

Valdimar Briem

BEHAVIOUR OBSERVATION:

THEORY AND APPLICATION
IN PSYCHOLOGICAL RESEARCH

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**Til foreldra minna,
Haralds og Margrétar Briem.**

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Any work, although in the end carried out by a single individual is not ever independent of the influence and help of others. The nature and degree of the influence varies, and is not always immediately apparent in the finished product. But surely enough, it is there. The present thesis is the result of many years of labour which has often been hard, sometimes painful, always time-consuming, and occasionally rewarding. And if one knows where to look in it and looks closely enough, the influence of many people may be detected.

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The thesis includes the following five publications:

1. Briem, V. & Nyström, M. (1978) The detection of infants' facial movements. **Psychol. Res. Bull., Lund Univ., 18, 8.**
2. Briem, V. (1983) The recording of behavioural data with a portable data-terminal. **Psychol. Res. Bull., Lund Univ., 23, 3.**
3. Briem, V. & Nyström, M. (1984) Application of behaviour observation for investigating relative work content, behavioural style, and social interaction in telecom work. 1. Behavioural taxonomy. **Psychol. Res. Bull., Lund Univ., 24, 3.**
4. Briem, V. (1985) Application of behaviour observation for investigating relative work content, behavioural style, and social interaction in telecom work. 2. Sequential dependencies. **Psychol. Res. Bull., Lund Univ., 24, 3.**
5. Briem, V. (1986) Temporal organisation in the facial behaviour of neonates in Active Sleep. **Behaviour, in press.**

Behaviour Observation:

Theory and Application in Psychological Research.

Valdimar Briem

"Description is never, can never
be, random; it is in fact highly
selective, and selection is made
with reference to the problems,
methods, and hypotheses the
investigator has in mind."

Niko Tinbergen.



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Introduction.

The observation of behaviour is an activity which may to some people seem very straightforward; they would maintain that all one has to do is keep one's eyes open to see what is happening in front of them. To others, myself included, the process of behaviour observation does not seem so uncomplicated; instead it is an activity during which much time and effort must be laid down to clarify the various issues involved, and a profound understanding of the assumptions underlying the classification of observed behavioural objects is needed in order to explain satisfactorily the results obtained from the study.

For instance, let us imagine a situation where a man, Jones, is observed to cross the road, and an observer records the relevant details of his journey. Both Jones and the observer come up with accounts of this event where only some of the details match and others differ. Thus, the observer may describe the sequence of Jones' actions on the way across the road, while Jones himself describes his motives; or the observer may infer a motive for the crossing, while Jones describes his physical movements. Jones and the observer may, in spite of the different accounts, eventually agree on an 'official' version of Jones' passage from one side of the road to the other. For most of us, these agreements and disagreements are quite natural, and only exceptionally would they in an everyday setting be regarded as more than trivial. Then, making the road-crossing behaviour the object of an extended study presupposes that Jones' behaviour is in some way interesting enough for us want to ask questions about it. Thus, Jones may have rushed headlong into the road and nearly been run over by a passing car. In which case we may want to know if this is the way Jones behaves generally, or if this is an accepted practice in Jones' family, or if Jones saw a particularly beautiful woman on the other side of the road etc. There are also other possible considerations, such as where and when the behaviour took place; was it during the rush hour in the centre of town, or on a quiet, residential street in the middle of the night?

It is clearly possible to ask a seemingly straightforward question about a person's behaviour, such as "Why did Jones cross the road?", to which no immediately available answer may be acceptable at its face value. For me this constitutes an ample reason for continuing the stringent observation of the behaviour involved, in order to find out at least what the sources of the disagreement are. Not that I believe that we shall ever be able to accept any single answers to this type of question as incontrovertible 'reasons' for behaviour; but at least by examining the issues involved, we shall be better able to determine what types of answers are acceptable as 'reasons' for the behaviour observed by us. (For an extended discussion of Jones and his reasons for crossing the road, cf. Peters, 1958).

It is my aim in this thesis to present some of the methods that may be used in this endeavour, as well as to proffer arguments for **why** these methods should be used and **how** they may most effectively be applied in the study of behaviour.

I begin by defining the term 'behaviour', and my definition is similar to that generally used in behaviour observation studies. Observed behaviour is here normally assumed to have a **structure** in both space and time, by which we may be able to identify the behaviour when we see it occurring. In fact, the behaviour may not be identified by just a single but several structures, each of which may do equally well for determining its identity. Thus, the behaviour may be seen as 'just' movement, it may be a movement in a certain direction, it may have cause, or it may have an identifiable purpose. I attempt to show that the structure which we observe is, in fact, the end-product of an inference process, and that we impose this structure on another structure which we assume underlies the observed behaviour. The underlying structure may be one of several types, and our choice of a **mode of description** for the behaviour is the result of a series of more or less immediate decisions based on our general world view as well as what we wish to achieve in the observation study. Thus, with regard to Jones' trip across the road we might say either "Jones walked into the road, and an oncoming car stopped suddenly", or "Jones forced the driver to stop his car by walking into the road in front of it". In the first case we 'just' describe the sequence of events observed, while in the second case we infer a motive for Jones' actions.

However, the structure of the behaviour observed cannot be explained just by reference to our choices and preferences, and I argue that in order to arrive at an acceptable account of behaviour in general, we usually feel obliged to invent some further structures, or **models**. The observed behaviour is subsequently regarded as a logical consequence of these models. Variation from behaviour predicted from the model would then be seen as deviations from the norm. Thus, the behaviour may be seen as the consequence of innate or learned behavioural 'programs', motivating 'forces', neural 'mechanisms', and biological 'clocks'. But whichever intervening structures we employ, we are likely to accept the simplest and most generally applicable and comprehensible models as valid **descriptions** and **explanations** of the behaviour studied.

I maintain that the models that we use are not only convenient but in fact essential for describing and explaining the behaviour which we observe. Therefore, special attention must be paid to these models in behavioural theory. It happens all too often that the models, on which our behavioural descriptions are based, are not explicit, and sometimes they are logically flawed. One type of structure employed for behavioural description and explanation is a '**hierarchy**'. Hierarchical models are of course equally susceptible to misconstruction as other models, but I discuss them in detail because of their special importance for behavioural theory. As this type of model may be succinctly defined as 'a set of elements with a relation' (Dawkins, 1976), I subject these two phenomena, i.e. behavioural **elements** and **relations**, to an extended analysis. I attempt to demonstrate that if the elements and relations that a model is made of are adequately defined and correctly used in accordance with these definitions, the model may be applied meaningfully; otherwise the model will be internally inconsistent and possibly also gravely misleading.

I then endeavour to show that models, especially ones of a hierarchical type, are a very basic means that we as human beings have of **perceiving** and generally ascribing a meaningful structure to our **cognitive** world. But our models of the world are also in a constant flux, continually undergoing modification as our experience and knowledge increases, being stable only as long as it is necessary or convenient for us to let them guide our own behaviour or our perception of that of others. But it is essential that the way we use our cognitive tools does not confuse the issues to which they are applied. Thus, both the **reliability** and the **validity** of the models and their components must be maximized in behavioural observation, and only then can we discern the relevant and meaningful qualities of the behaviour observed.

After having explored some of the theoretical implications of the way we use models in behaviour observation, I go on to examine how this knowledge may be applied in practice. In particular I look at how behavioural **taxonomies** may be constructed and used in observation, **a priori** ones before and **a posteriori** ones after a particular observation study. The way we go about this has considerable practical consequences for the kinds of conclusion that we may draw from our behaviour observation studies. As examples of this **application** I include 5 of my own published papers. One of these papers contains a description of an early version of the data collection methods that I have used, while the remaining 4 demonstrate the use of the behaviour observation methodology in two different areas of psychological inquiry, viz. infant development and the study of work behaviour.

The conclusion that I come to at the end of the thesis is that it is imperative for anyone carrying out an observational study of behaviour to be fully aware of the implications of the theoretical tools at his disposal. Only then will the investigator be able to carry out a meaningful study and interpret dependably the results obtained. I also believe that this kind of awareness is the only way in which one can add significantly to the understanding of the phenomena involved and so stimulate the general development of knowledge in this field of study.

The study of behaviour.

The term 'behaviour' may be used to cover a wide range of phenomena of many forms and features. As the term is applied, it may refer to any change that can be measured both in inorganic matter and in living and even conceptual systems. Behaviour in its most general sense is a change that may be measured in any structure from one moment to another, and is in this way seen to be extended both in space and time.

In the present thesis I have chosen to limit the usage of 'behaviour' to that normally employed in psychology and ethology, although with some restrictions. 'Behaviour' is defined here as a progressive change in any observable aspect of an organism. Hamlyn (1953), in his discussion of the concept, states that " 'Behaviour', 'conduct', 'activity', and 'action' are words of one particular type, though there are differences between them. 'Movement', 'reaction', 'reflex', and the like are of a very

different type. ... Behaviour is not a series of movements" (p. 145). This definition of behaviour is similar to that of everyday usage, and is not the one adopted here. Instead, a more general meaning is adopted, where 'behaviour' is taken to include 'movement', 'reaction', and 'reflex' as well as 'activity' and 'action', and the two types defined by Hamlyn then constitute subclasses of behaviour. There are, of course, also differences in meaning between the labels within the class. However, I do not include 'conduct' in the present definition of 'behaviour', nor is it taken to include the notion of 'purpose' in the everyday sense. Some of the more relevant of the differences in meaning between different labels are discussed extensively below, as are also the different ways of using the term 'behaviour' and the consequences of these different uses.

When we are confronted with behaviour we are seldom in any doubt as to what it is. Different people's judgement that behaviour has occurred will not be at variance, but it often takes highly trained observers to agree on what the particular behaviour was. People without special training in observing behaviour tend to extract from it information about actions, intentions, states, and interpersonal relations, i.e. things that are connected with human purpose and have meaning in our everyday social context. But for the scientific observer, it may also be possible to discern in the same behaviour other aspects which are not readily seen by the ordinary person. Thus, the scientist will define the behaviour under observation in accordance with his objectives and the observational context, and within this frame of reference he will then observe the flow of behaviour with minute scrutiny and, what he hopes will be, total accuracy. In this manner the trained scientific observer seeks to attain both meaningfulness and objectivity in his observation.

But how do we achieve this attractive state of observational practice, i.e. how should behaviour be studied in the most meaningful and objective way? How should the behaviour under study be represented to begin with, and what techniques and instruments should we employ as an aid in our observation? What we know with certainty is that, in order to be able to discern many of the lawful dependencies in the streams of organismic behaviour observed, we have to employ techniques that are more powerful than those available to us in ordinary, everyday observation. In other words, the way we conceptualize and describe behavioural events in our everyday language is not exact enough to be of use in most scientific investigations of behaviour. Also, the labels we put on these events tend to influence the way we see them, and by the same token, the way we structure our mental world tends to determine the way we perceive the things and events around us. In the case of the organismic behaviour that this thesis is concerned with, I shall refer to the results of this perceptual process as "the imposed structure" of behaviour, which is to be contrasted with "the underlying structure" of the behaviour under study. The former of these is the conceptual apparatus that we have at our disposal in our task of behaviour observation, while the latter is what we endeavour to discover with the help of this apparatus.

The imposed and the underlying structures.

As already stated, the imposed structure is the one which we perceive when we observe a stream of behaviour. It is a structure which we have learned to see, and if we have never trained our faculty for objective observation, we shall be hard put to see more than one structure in the behavioural stream. But as I have implied, there are other ways of perceiving than just this one, in fact an endless number of ways, any of which we are capable of training ourselves to use during behaviour observation. As an organism behaves, it produces behaviour by making use of the muscles and other mutable parts of its body. These changes in appearance is what we observe. But our senses are not ordered in the same way as a camera or a tape-recorder, and the events that take place are not registered in every small detail of movement or change of appearance in our minds. Instead, we gather impressions and ideas about what it is that is happening, we 'perceive' an organism's behaviour. During this process we may add or subtract details in such a way as gives a recognizable form to the behaviour that we are observing, and more likely than not we end up with a meaningful sequence of behavioural events. But the order we perceive in the behaviour may only be superficially related to the structures that underlie this perception, and even if we succeed in registering the form of the behaviour accurately, there is a possibility that we may miss the functional or causal significance of the observed behavioural events altogether. Thus, the organism that we are observing may, for example, signal a threat to another organism by raising its left eyebrow and pulling back the corners of its mouth; but without a special training in observing this organism's behaviour, the observer may wrongly interpret this combination of forms as the sign of a friendly attitude. In this case an inappropriate causal structure would be perceived. What we must, of course, realize is that the underlying structure of behaviour is always inferred from the imposed structure, and that without an imposed structure, an underlying structure cannot be seen. (1)

What, then, would the 'real' significance of the observed behaviour be, if it is not the same as the meaning which we normally perceive it as having? An organism produces behaviour, and this behaviour has a structure. The structure may be regular or irregular, it may be rhythmic or arrhythmic, it may be predictable or unpredictable. Organismic behaviour is a function of living beings, and being such entities we tend to expect ourselves to have some intuitive understanding of its structure and meaning. Indeed, we have some reason to expect our perception of the behavioural production of other human beings and some other animals to be reasonably accurate, as both the processes of production and perception are organised by nervous systems that are governed by analogous principles. However, behaviour is an endlessly variable process, and because of this diversity, it is likely that we at times come up with interpretations of acts or sequences of behavioural elements which do not optimally represent the underlying structure of the behaviour under study. Thus, while there may in fact not exist an unambiguous interpretation of the observed behaviour, it may be possible anyway to determine its appropriateness with some accuracy.

It was pointed out above that our ordinary perception of behaviour tends to be in terms of individual or social needs or intentions, rather than in such terms as may be related to the phylogeny, ontogeny, or survival of the organism under study, and in a human context, this may often be an appropriate way of representing behaviour. But because of the strong expectations of behavioural outcome associated with this type of representation, it is often heavily biased by the observer's individual experience. In order to guard against this, more objective modes of observation tend to be chosen in scientific behaviour observation. In general, one has to be aware that important features of behaviour may be overlooked in observational studies by the observer imposing on it an inappropriate structure. Many of the mistakes made in such observation may be avoided by the investigator obtaining a sound knowledge of the normal behaviour of an organism before setting up a catalogue of items of its behaviour for use in observation. Similarly, getting to know the behaviour of organisms that are closely related phylogenetically to the one under study may help the observer to arrive at correct conclusions from the sequences of behaviour observed. Many of these factors have been pointed out by previous investigators of this area, e.g. Hutt and Hutt (1970).

The surface structure of behaviour.

An organism's behaviour may be described by an observer in various ways, for varying reasons, and to varying degrees of fullness. But before it is possible to begin this enterprise, several important things must be done. These prerequisites of behavioural description may be thought of collectively as a construction of a model of the behaviour under study, a model which serves as a general basis for the study, and this model may be either implicit or explicit. Thus, the observer must begin by specifying his universe of discourse.

The initial model-building is primarily guided by a series of decisions about behavioural representation by the observer. The first decision which must be made concerns the underlying behavioural structure. At first, an appropriate question would appear to be "What is the behaviour **really** like?" But as I shall discuss below, there are more ways than one of describing reality, and therefore, the problem arises as to which of these aspects should be represented in that description. The first decision soon comes to be stated as the question "How does the observer **prefer** to represent the behaviour?". This decision may also be taken to concern the observer's belief as to what the behaviour 'really' is about, and what he believes to be the most appropriate mode of representation according to this belief. The three main alternatives for representing the behaviour are in terms of its formal appearance, its function, usually in the terms of enhancing the organism's chances of survival, or the immediate causes and effects of the behaviour. It is important to distinguish between these modes of representation of behaviour, and they will, therefore, be the subject of an extended discussion below. Thus essentially, the first decision about behavioural representation may be resolved into a choice between a limited number of distinct, descriptive modes which may be applied to the behaviour under study.

The problem of deciding on an acceptable, conceptual structure, by means of which the behaviour to be investigated may be represented, is a fundamental one, and must be resolved successfully in the early phases of the construction of a behavioural model. In this connection it is also necessary to define the classes of the behaviour to be observed. The second, major decision involved in the initial model building concerns the imposed structure, and may be stated as "What is the most **convenient** way of representing the behaviour?". This decision involves primarily the observer's choice of method for observing the behaviour, i.e. which behavioural classes are the most appropriate ones in this particular context, how many separate classes are employed, how big the segments of the organism's behaviour included in each class are, how long each behavioural unit in the classes may last, whether the behaviour should be observed continuously or sampled, which apparatus to use etc. These two major decisions are not independent of each other, but may conveniently be treated separately.

A third, less general decision, which will also be made here, may be stated as "What **type** of behaviour are we dealing with here?". Thus, the behaviour under study may be that of a solitary organism or a group of organisms; it may be directed towards a definite goal, or involve interaction and communication between organisms; it may take place in favourable or unfavourable circumstances for this particular activity; etc. This decision is not entirely independent of the first two decisions, but may, again, be treated separately. The order in which these decisions are enumerated here is not necessarily the order in which any particular investigator makes them, and there are, of course, other decisions of a more immediately practical type which the investigator makes all the time.

The behaviour of an organism may be seen as a physical structure which is extended in time, and during time its physical dimensions are successively transmuted. The different patterns of these transmutations are what makes it possible to identify distinct units in the streams of observed behaviour. The sequence of patterns may, further, be referred to as the 'static' structure of behaviour, and the mutual relations between patterns in the sequence as the 'dynamic' structure of behaviour. Even though each organism has only a small number of effectors with which to form its behavioural patterns, the possible combinations in space and time are virtually infinite. However, any organism's being is delimited by the fulfilment of a relatively small number of needs, and the number of successful ways that organism has of attaining these goals tends to be fairly limited. Consequently, several more or less dissimilar patterns may usually be equated with respect to their function, and a complicated sequence of observed behavioural events may be seen as a series of actions for achieving a particular end. A complex structure can thus be reduced to a simpler one, and the dynamic structure derived from the observation of a particular organism will usually be of quite manageable proportions.

The temporal structure of an organism's behaviour is considered as the sequence through time of those physically structured units. Or as Hinde (1975, pp. 3-4) has expressed it:

"Each item of behaviour forms a link in a nexus of events which precede and follow it. If we focus on the behaviour, we refer to some of the former as causes and some of the latter as consequences. ... In a broad way, beneficial consequences are referred to as 'functions'." However, the units seen in the behavioural stream need not necessarily be conceptually linked to an intention to perform a movement or a sequence of movements, or be associated with a certain end state, a biological function or a need, although it is often convenient to do this. The identity of the units may, instead, be linked to their morphological structure as it appears in the time interval in which the units occur. These different ways of representing the units of behaviour are subject to a decision by the observer, i.e. to his representational preference, and they may be referred to as the 'descriptive mode' of an observation study. The two descriptive modes, which are referred to here as 'functional' and 'morphological', respectively, according to the usage of Hutt and Hutt (1970), have been discussed by Hinde (1982, p.31): "Two methods of description are available. 'Physical description' involves reference ultimately to the strength, duration and patterning of muscular contractions, though it is usually limited to patterns of limb and body movement. ... 'Descriptions by consequence' do not refer to particular patterns of movement but cover all patterns that lead, or could lead, to the result specified: 'Approaching the nest', or 'Hiding from the hawk' are examples." These descriptive modes have also been discussed at some length by Purton (1978) who includes 'categorization according to causation' as a third mode of description.

Behavioural causes.

In any organism's environment there are other organisms whose behaviour also progresses through time alongside that organism's behaviour in an analogous fashion. Some of these organisms are conspecifics, others belong to different species. It may be seen that a particular organism's behavioural structure may be influenced by units of behaviour occurring in its own behavioural stream, and also by units occurring in other, neighbouring organisms' behavioural streams. Some of these influences on behaviour may be seen to be of a social type, while others may be parasitical, predatory etc. 'Social' behaviour tends to occur primarily between conspecifics, and its function is, among other things, probably to clarify the past, present, and future relations between individuals in a group. Such a hypothesis has been proposed by Hinde (1975) for threat displays and agonistic behaviour.

Behaviour may be said to be caused by either inner or outer factors, or both. According to an extreme variety of behaviourism it might be said that no reference to inner causative factors is needed in order to explain behaviour. As regards behavioural ontogeny, some extreme behaviourists would also maintain that, apart from a limited number of reflexes, different forms of behaviour appear in all relevant respects as a consequence of environmental influences. During the 1950's there raged a serious controversy between these behaviourists and some more biologically oriented investigators who maintained that much of

the behaviour that appears during development does so mainly as a result of the maturation of the appropriate neural and anatomical structures. The 'innate vs. learned' ('nature-nurture') controversy was eventually resolved by the recognition that this dichotomy was more artificial than real. This recognition was brought about partly by an increase in knowledge about behavioural ontogeny through empirical work, and partly through "the blending of the functional and causal behavioural frameworks" (Purton, 1978).

The outer causation of behaviour may, at first sight, not constitute a problem for observation. We tend to perceive happenings in terms of causes, which in the case of inanimate objects are often seen to be physical forces, and in the case where organisms of a higher order, such as ourselves, are involved, the causation may be in terms of motives and reasons (cf. Peters, 1958). Interaction between organisms and the environment may be seen as chains of causes and effects. Events in the environment such as the weather are, for example, often the causes of quite distinct behaviour patterns. Thus, if it is cold I put on warm clothes, and if it rains I don my wellies. However, problems of interpretation do arise when choices between several different lines of action must be made, or when the tendency of some outer stimulus to elicit a specific response is being generalized to a population of individuals. In the first of these cases we may have a number of responses which occur at different times when a stimulus is presented to an organism; in which case we have a single cause but many possible effects, a situation that can be difficult to resolve within a simple cause-effect framework. In the latter case a problem arises when a given response may only be elicited from certain individuals of a given species but not others. Then the ascription of a causal relation has to be qualified in some way, either by admitting that it holds only for certain individuals, or that it holds only at certain times and not at others. In experimental investigations of the kind usually carried out in psychology, a situation requiring an objective decision would lead to a set-up where a well formed hypothesis could be tested under controlled conditions, and its validity assessed statistically. In a comparable ethological observation study, the dynamic relations between different behaviour patterns are investigated. Although inferences about relations in identical sets of behaviour patterns might be drawn in both types of investigation, the relations inferred in the experiment would probably be causal, whereas relations in the observation study would tend to be probabilistic in nature, i.e. expressed in terms of the likelihood of several different behavioural outcomes. The size and nature of the units employed to code the behaviour in the two cases would most probably also differ.

Behaviour production.

Although the 'innate vs. learned' controversy has been abandoned as unfruitful, there are some aspects of it that provide good examples of how problems encountered in behaviour observation may be resolved by shifting the locus of emphasis in their formulation. (2) The question of the definition of 'innate' was touched upon by Hebb (1953) who pointed out that it only has meaning in relation to what may be defined as 'learned'.

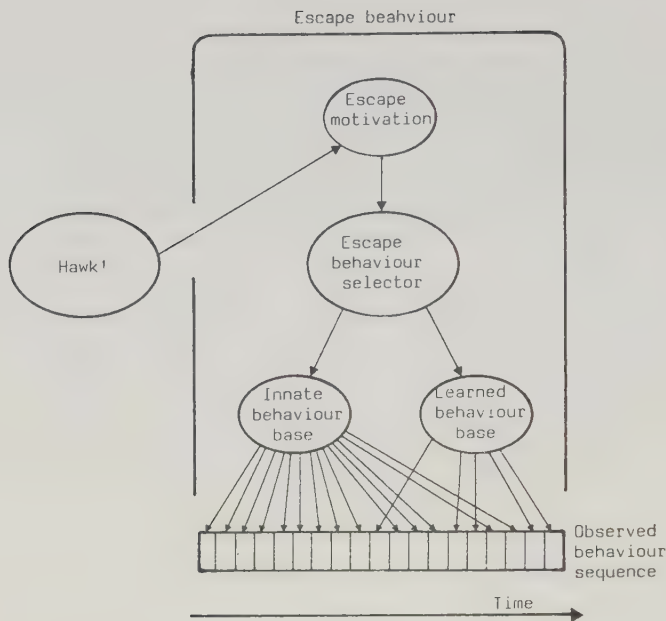


Figure 1.a. A fixed element model of escape behaviour (Lorenz).

Tinbergen (1963) also points out that the conclusion that a given behaviour pattern is 'innate' "can only be formulated correctly in negative terms, in describing which environmental aspect was shown not to be influential", i.e. by elimination. Furthermore, in considering the respective influences of innate and learned factors in the ontogeny of behaviour, Tinbergen argues for, what I shall call here, a 'modified base' for behaviour production. Tinbergen states (p. 425) that "we must allow for the possibility that ... an environmental property ... is required for the proper 'programming' of part of the ... behaviour machinery". Thus, "many behaviour patterns can be said to be at the same time innate and learned, or partly innate and partly learned", and "many interactions with the environment which result in increased efficiency are additive to some machinery that was already functional". Tinbergen contrasts this view to that of Lorenz (1937): "Lorenz ... coined the term 'Instinkt-Dressur-Verschrenkung' indicating that learning processes were often, so to speak, intercalated by non-learned parts of a behaviour chain. This has given rise to the idea that, if we could only split up behaviour chains in smaller and smaller components, one could always reach a state where some components could be labelled as innate, others as learnt or acquired". Tinbergen concludes: "I cannot see how ... it can be fruitful to look for innate and learned components, however small".

According to this view, organismic behaviour may be ordered along a continuum, from patterns which are very little affected by learning to patterns whose form is mutable and almost entirely shaped by the experience of the organism concerned. Thus, observable behaviour would be affected by phylogenetic adaptation and adaptive modification of the behaviour of individual organisms.

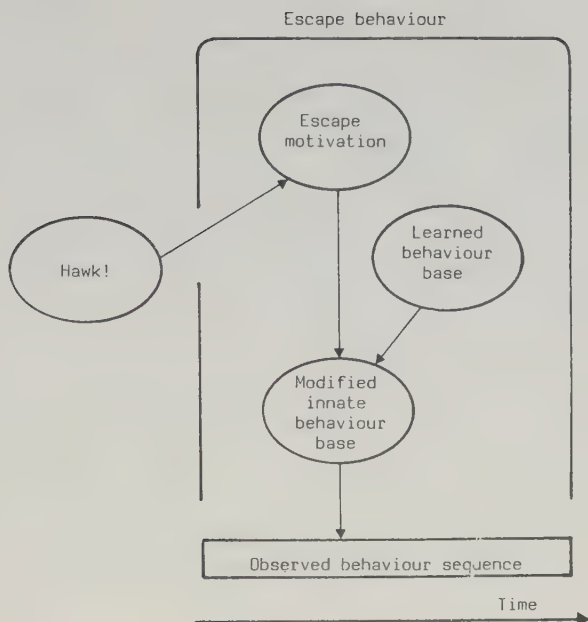


Figure 1.b. A mutable element model of escape behaviour (Tinbergen).

In contrast to this, Lorenz (1965) proposes that, while the influences of learning and innate factors may be discerned in any organism's behavioural stream, the innate elements of behaviour are not actually modified by individual adaptation. Instead, elements with a phylogenetically fixed structure are mixed with learned behavioural elements, and the balance of ingredients in the mixture depends, among other things, on the level of development of the function involved.

The two theoretical viewpoints expounded above may be reconciled through a modelling procedure. I begin by representing the respective hypotheses of Lorenz and Tinbergen, as I understand them, as 'minimal' models of behaviour, i.e. including the least number of assumptions. For purposes of illustration I have chosen the (sparrow) escape behaviour implied in the sentence "Hiding from the hawk" (cf. above). The behaviour as it might have been presented by Lorenz is shown in Figure 1.a, and the same behaviour as it might be from the point of view of Tinbergen is shown in Figure 1.b (3). If both models are seen to represent behavioural programs analogous to those run on a computer, it is clear that the one in Figure 1.b, the 'modified base model', is the more efficient and would take considerably less time to execute; the program in 1.a, the 'fixed element model', requires that every time the behaviour occurs, a new selection be made of all the escape behaviour units in the sequence, whereas the sequence in 1.b would be executed as a single unit. But it may also be argued that the model in 1.a represents the more 'successful' behaviour, as it is more flexible than that represented in 1.b!

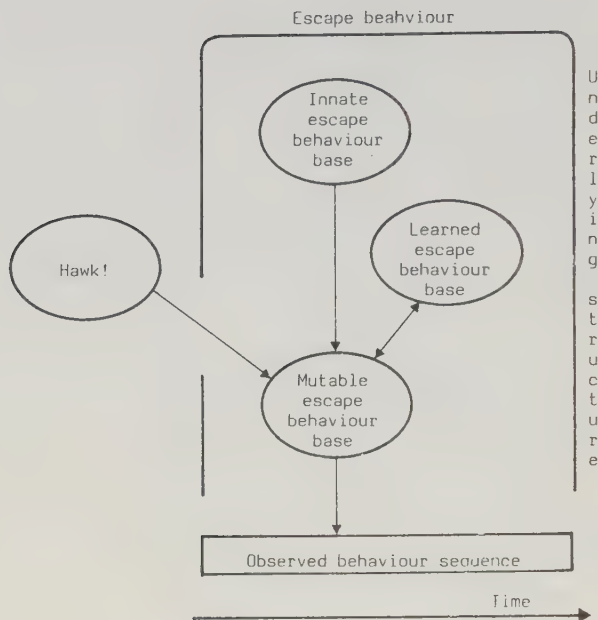


Figure 2. A mutable behaviour base model of escape behaviour. Here, 'motivation' is not included as an explanatory device, but information feedback between the mutable and learned behaviour bases is assumed to occur.

It is clear that having two distinct behavioural systems, one innate and the other learned, operating in tandem to determine the surface structure of behaviour, as in the fixed element model, would not be biologically economical. This has been pointed out by Tinbergen (1963). However, behavioural economy does not require that innate behaviour be modified in the way implied by Tinbergen; the composition of the behaviour produced by the organism might equally well be a mixture of innate and learned elements as proposed by Lorenz. And it is not necessary either to make a choice between these two alternatives. Instead, we can postulate a 'mutable behaviour base' at an intermediate level between the behaviour that we can observe and any underlying innate and learned behaviour bases. We can also imagine a two-way connection between the mutable and learned bases, where the success of the behaviour performed is continuously fed back to the learned base. A single system of this kind, successively shaped by both innate and learned factors, but containing behavioural programs ready for execution at critical moments, would be capable of achieving far greater speed, efficiency, and flexibility in the production of the appropriate behaviour, thereby increasing the survival value of the organism concerned. A suggestion as to how a model of such a system may be formed is shown in Figure 2.

Digging deeper.

If we wish to be able to provide more clear-cut answers to such questions as "What are the nervous mechanisms that govern the outer expression of behaviour?" and "What is the inner causation of behaviour?", then we must have recourse to powerful explanatory models. Many such models have been proposed, as throughout the present century students of behaviour have been exploring the power of different, postulated, underlying principles to explain the observable forms of the behaviour of organisms. Some of these principles have found favour with other investigators, while others have not. One of the most popular types of explanation has been in terms of **motivation**, and this is the type that has longest guided ethological research.

In order to understand the function of motivation in ethological explanation, it is necessary to recall the two principles that are the basis of all ethological reasoning from Lorenz onward. These principles are both concerned with survival, the survival of the individual and that of the species. It is not difficult to find the reason for this as ethology is properly a branch of biology, and biological explanation tends to be in those terms. Motivation is then considered as the **driving force** behind the execution of these evolutionary imperatives when they are manifested in the behaviour of individuals and groups. Thus, Lorenz' hypothesis (1950) of the internal control of behaviour is in terms of motivational energy. The energy is here of a non-specific kind, but may drive different innate mechanisms when appropriately channeled. Some theorists have followed in Lorenz' footsteps and put forward similar hypotheses of a general activation or energy for powering the execution of innate movement sequences, while the kind of motivational energy envisaged by other theorists (e.g. Tinbergen, 1950) may be somewhat more 'action specific'. However, this is not of importance, as the associated models may be adjusted so as to accommodate mechanisms for redistributing the postulated energy. Tinbergen's treatment of 'displacement activity' in this manner in his theory of motivated behaviour (1951) is an example of such redistribution.

In addition to having an energizing property, motivation may be regarded as a **guiding principle** for behaviour. This latter property is partly what is implied when motivation is referred to as 'action specific'. In Tinbergen's model (1950) of motivated behaviour, which is used at various points in the present thesis for the purpose of illustrating different arguments, the specificity of the activation is seen to be related to the actual structure of behaviour, and it is manifested in the flow of energy between hierarchical levels in the model along predefined paths. Still another, related use of the concept of motivation is as a **framework** for groups of activities which are then seen as being specifically motivated. For example, a 'reproductively motivated' stickleback will perform certain sets of actions in the presence of certain environmental factors and releasing stimuli. The common denominator for these sets of activities is the reproductive motivation.

The employment of motivation in an account of behaviour will always carry the added sense of something being powered. This begs the questions of what it is that is being powered, and what the nature of this energy is. One may also enquire how this energy is transmitted, stored etc. (cf. Peters, 1958; Hinde, 1960). In the minimal model shown in Figure 2, motivation has been left out, partly as it is not needed for explaining the behaviour modelled, and partly because leaving out the motivational link between the outer 'cause' of the behaviour and the inner base for it affords the model a greater flexibility, as now behavioural decisions may be made without the immediate direction of the internal energizing principle. This will be discussed in more detail in a later section.

Through the work of investigators such as Lorenz and Tinbergen the biological foundations of behaviour have been made visible. The work of exposing this structure further is under way, but there is still a lot to be uncovered. One of the areas where a fair amount of work has been carried out concerns the neurological mechanisms which govern behaviour. We know that the foundation on which all behaviour rests is biological, and that some behaviour has a structure that appears to be very little affected by practice or learning (cf. Lorenz, 1965). From the pioneering work of investigators such as Lashley (1951), von Holst and von St. Paul (1963), Willows (1967), and more recent work of other investigators on the neuropsychology of the human brain (e.g. an der Heiden, 1980; Risberg, 1980), we know by now something about the location in the central nervous system of the control centres for certain motor sequences, as well as which cortical areas are maximally active during the execution of various tasks involving motor planning and production. But we still do not know how the genes dump their motor information onto the neural structure of an organism, nor do we know if or how the same neural circuitry is used for relaying both innate and learned motor information to the organism's effectors (cf. Hebb, 1953). And while studies employing brain tissue ablations and central, electrical stimulation may give striking and significant results, we usually do not know, because of the complexity of the functional organisation of the CNS, exactly where on the way from the storage locations in the brain to the effector machinery of the organism we have managed to place the electrodes which stimulate the performance of the movement sequences observed.

Tracing the neural substrate of behaviour is but one step on the way to achieve a detailed description of an organism's behaviour patterns, even if some theorists consider it as the ultimate goal of behavioural description. But at our present stage of knowledge this particular achievement is still far off. A much more profitable way of describing behaviour, one which we are well advised to concentrate on, is related to organisation in terms of systems (cf. Baerends, 1976). Systems thinking in behavioural science may be traced back to the 1920's to the work of Weiss and Bertalanffy (cf. Gray & Rizzo, 1973). Some years later, ethologists such as Baerends (1941) were employing hierarchical groupings in the systematic representation of observed behaviour, and a few years later Tinbergen (1950) proposed his hierarchical model to explain the relations between the various components of the structure of motivated behaviour. These

studies in behavioural science could be linked to work being done in applied mathematics (e.g. Shannon & Weaver, 1949). Thus Miller & Frick (1949) proposed that certain stochastic models might be applied to the description of behavioural systems, an idea that is still being developed (e.g. Metz, 1974; Gottman & Bakeman, 1979). Another fruitful idea to emerge from thinking about organismic behaviour in terms of systems was that of behavioural 'Plans' (Miller et al., 1960). This concept incorporates the idea of hierarchical organisation in behaviour, as well as a representation of motor or even cognitive performance as the result of the execution of a series of related, but self-contained routines. Behavioural production can then further be seen to be organised on several, different levels, and within each level the behaviour could be represented as a sequence of elements. These ideas have been taken up and developed further by, for example, Nelson (1973) and Dawkins (1976) (cf. below).

Flow-diagrammatic representation is intimately coupled to systems description. It is particularly useful in the representation of a sequence of events where the physical structure of the system in which the events take place is known, especially where a detailed blueprint of the processes involved is available. But even when the physical structure is not known, as in the representation of the relation of underlying structure to observed behavioural events, flow diagrams may be helpful. Thus, it was demonstrated above how a simple flow schema, or a minimal model, may be of use in deciding on the most likely chain of events leading up to a behavioural sequence, and may even be used to suggest new ways of explaining it.

Human behaviour and behavioural planning is inextricably bound up with cognition and language. As a consequence, it has seemed appropriate for many investigators to draw a parallel between linguistic structure and that of other human behaviour. In the early 1950's Birdwhistell put forward the proposition that non-verbal communicative behaviour was organised according to similar principles as linguistic communication (cf. Birdwhistell, 1971), a parallel which he explored in a series of studies, many of them empirical. Birdwhistell eventually devised a system for observing minute changes in behaviour, but as this demands the observation and simultaneous registration of a large number of small behavioural units on a time-scale with a very fine resolution, his empirical work met with some practical difficulties. More recently, Condon and his collaborators have carried out a series of experiments along similar lines to those laid down by Birdwhistell, which showed that the temporal micro-structure of observed linguistic and non-verbal behaviour production was closely linked (Condon & Ogston, 1966, 1967; Condon & Sander, 1974).

Another line of research linking human behavioural structure to that of language is based on the work of Noam Chomsky. Chomsky (1957), investigating the structure of language, proposed a new kind of grammatical representation which was called 'generative grammar'. This system included a hypothetical, 'deep structure' underlying linguistic behaviour. The deep structure was suggested as the most basic way of internally representing an idea or concept, and may be considered to correspond to Kantian a priori knowledge (cf. e.g. Bennett, 1966). Furthermore, this

basic structure had associated with it a set of transformation rules by which the deep structure is transformed into the verbal utterances produced by speakers of a particular language. Adopting this scheme, Marshall (cf. Hutt & Hutt, 1970) showed that it was possible to simulate the behaviour of pigeons in a computer program constructed according to the rules of a simple generative grammar such as that proposed by Chomsky for human language. A similar, grammatical model has been explored by Fentress and Stilwell (1973) for certain movement sequences in inbred mice. Thus, it seems that at least some of the behaviour of other organisms is organised according to principles which are analogous to those extricable from the results of the cognitive efforts of human beings.

Temporal patterns.

Behaviour is extended in time, and during its extension has a structure in time. The temporal structure is basically of two kinds: Firstly, sequential dependencies between elements in behavioural streams of the kind mentioned above, and secondly, periodically recurrent phenomena of primarily internal origin, such as diurnal activity rhythms and behavioural states, recurring needs, and brain rhythms. The sequential dependencies between elements defined a priori are derived by analysis, and may ultimately be considered to be indicative of the deep structure of the observed behaviour. The kind of analysis performed here will often be the inductive testing of a model of the behaviour, and the appropriateness of the conclusions drawn about its structure will depend on the behavioural units and the models chosen.

The latter class of phenomena, which may be said to set the stage for the acts of the former kind, has mainly received the attention of neurophysiologists and psychologists. One of the biggest areas of research here has been that connected with diurnal rhythms and sleep. This research started already in the 1920's, but received a strong impetus through the research of Kleitman and his collaborators in the early 1950's (cf. Kleitman, 1963). Further interest in the area was aroused when Dement and Kleitman (1957) discovered a connection between dreaming and REM sleep. For about 10 years, from the mid-1960's onwards, there was an upsurge in the interest in the ontogeny of sleep, primarily through the work of investigators such as Prechtl (e.g. 1974) and Wolff (1966), as well as in the relation between behavioural states and psychological factors. Further understanding of the neurochemical, physiological, and electrical phenomena associated with sleep has been achieved through the work of Jouvet (e.g. 1969; 1980), Johnson (1973), Oswald (1980), Morrison (1983) and others.

By now we have obtained a fairly clear, general idea of how biological rhythms operate, but in relation to this, surprisingly little is known about why these rhythms emerge, what their function is, and what the relation is between the different rhythms observed in the same organism. The available answers to these questions come primarily from biology, where it has proved possible in a number of cases to link biological survival functions to the action of rhythms (cf. e.g. Huntingford, 1984,

pp. 160-166). Furthermore, it may be shown that both higher and lower organisms' biological rhythms tend to function as clocks by which they organise their behaviour. Our human behaviour is a typical example of this function, and Harcourt (1978) has, for example, also shown that the daily life of the mountain gorilla is divided into distinct periods of activity characterized by different types of social interaction patterns.

The activity rhythms of organisms may be suggestive of how the interaction of these organisms with their environment and other organisms in it may most profitably be studied. However, it is the short-term relations between elements in the streams of behaviour produced by organisms and the temporal contingencies found in the interaction of organisms with each other that are most often the subject of observational studies of behaviour. In addition to the work of Condon and his collaborators (cf. above), the rhythms characterizing both verbal and non-verbal interaction between people have been investigated by e.g. Byers (1976) and Gottman (1979). The ontogeny of these interpersonal interaction rhythms has been studied quite extensively during the last decade with regard to the communication between infants and their caregivers by a number of investigators, among them Thoman et al. (1979) and Brazelton and his collaborators. Thus, Lester et al. (1985) were able to isolate several rhythms with different, short, cyclic periods in the infant-caregiver interaction. These rhythms appear to be analogous to those activity rhythms that characterize the REM sleep of neonates, which will be discussed extensively below.

Describing and Explaining behaviour.

This thesis has so far been concerned mainly with examining the types of structure that we may discern in the temporal structure of organismic behaviour and the possible underlying causes for this production. However, I shall digress from this line of exposition and examine some of the conceptual and logical tools that we employ, explicitly and implicitly, in our study of behaviour. Then I shall attempt to show how the use of these tools shapes both the way we study behaviour and the results derived from this study.

It is possible to give an account of the structure of the behaviour under observation in several different ways. The two main possibilities that exist for this are either 'just' describing the behaviour observed or giving an explanation of it. Description and explanation are not exclusive of each other, as I shall show below, and description comes before explanation. Descriptions of behaviour range from the description of each observed element on its own without relating it to the description of the other elements observed, to a complete reduction of the behavioural process to a formal system, with various other possibilities in between these two extremes. But in general, it may be argued that in contrast to scientific explanation which will ultimately enable the investigator to understand the consequences of a behavioural process, description will only show the individual steps in the process without enlightening the investigator as to the causal or functional relations involved.

Even if there is a logical order between description and explanation, as description must exist before explanation is possible, it is often difficult to say when description ends and explanation begins; explanation may also be looked at as a description of a certain kind. Thus, in behaviour observation studies, giving an account of the static structure of behaviour constitutes a description, and giving an account of the dynamic structure constitutes one type of explanation.

There are several preparatory stages involved in giving a description of any behavioural sequence. Thus, to begin with, the universe of discourse and its contents of behaviour elements will have to be specified, together with the allowable generalizations of this material. The generalizations involved here are of the kind: 'If behavioural element A has properties a, b, and c, then it belongs in class P'. A descriptive mode for the observation may be chosen by observing the following rules of thumb: If the function of a movement or a sequence of movements is not known, select the morphological mode; otherwise, select the functional mode. Thus, we may decide to study the aggressive behaviour of some organism within a specific environment, and compare this type of behaviour with other, non-aggressive social behaviour. Within each of the superordinate classes that we have defined ('aggressive'/'non-aggressive'), we may also observe different sub-classes of social behaviour. As a part of this process, we define what is to be counted as behaviour belonging in those classes and subclasses. (4)

Only when we have defined and set up the study according to our needs in this way, are we in a position to observe the behaviour chosen more systematically. Behaviour observation is often taken to refer only to this last activity, which includes a coding of the observed behaviour, and may then be regarded as a basic form of description. Each assignment of a predetermined code or a label to an observed 'unit' is then seen to be analogous to the production of a 'descriptive statement', where the predefined units are the 'arguments' and the assignation of the label the 'function' of the statement (cf. Harré, 1960). When this activity is successfully concluded we can move onto the next stage. The subsequent description of the observed behaviour is usually extended further into some sort of systematization, either intuitively, as in the construction of ethograms and behaviour catalogues, or in a more sophisticated way with the help of taxonomic methods (cf. Sneath & Socal, 1973) or by the use of sequential or time-series analyses (cf. below). These methods are important tools for 'exposing' the structure of the behaviour under study, or to be more exact, composing a coherent picture of the dynamic relations that may be discerned between the behavioural categories defined a priori.

But 'behaviour observation' may also be taken to refer to the particular research process in which the actual observation and coding of behaviour is but one of the steps. The ultimate goal of behaviour observation in this sense is then the explanation of the behaviour studied. Thus, we are often not satisfied with just describing the static and dynamic structures of the behaviour; we may desire to be able to fit it into a wider context of explanation where relations between the observed behaviour and

other aspects of the organism's life, or more generally, the lives of other similar organisms may be understood more clearly. As with description, several different types of explanation are possible, depending partly on the classificatory framework into which the behavioural study is set. For instance, Purton (1978) has pointed out that the conceptual scheme employed in comparative psychology is often causal, with the explanations given in terms of 'causes' and 'hidden mechanisms'; while in classical ethology, in those instances where the discussion has been extended beyond the descriptive level, theorists tend to employ functional explanation of the behaviour under study. Purton states that "if the description involving function can be satisfactorily given, there is no further, and separate, problem of explanation, since the more one is able to specify a behaviour pattern in terms of its function(s), the more understanding one has of 'what it is for'" (pp. 654-655). And as the function of the behaviour is ultimately expressed as its survival value (cf. above), "such explanations fit the observed behaviour into its wider biological context, and in so doing they explain it" (p. 656). This is one possible way of explaining behaviour.

Generally, the main distinction between scientific description and explanation is that in the former we stay within and with the latter we go outside the immediate context of representation in an attempt to attain understanding of the phenomena that we are investigating. We can do this either by relating the present phenomenon to a past or a future context at the same level of discourse, or by describing it on a different level than that on which it was originally observed, usually in terms of something else. A means towards explanation is a simplification of the process under study, and a clarification of the logical relations between the elements involved in the process. Thus, in behaviour observation studies, explanation is often in terms of systems and models where the internal relations may be seen to be causal.

Models and other edifices.

A model has a less complicated structure than the thing modelled, and only certain, essential parts of that thing are emphasized in the model. The reason for building a model is seldom for the sake of description alone, but also for explanation, and even prediction and the generation of hypotheses. As a model is a simplified version of the real thing, built on a scale and of material that is more easily manipulated, it allows us to represent complex happenings in simple terms, different from those proper to the thing modelled, and to perform operations not otherwise possible. Therefore, a model does by its very nature constitute an explanation of the thing it represents. Of course, the quality of the explanations proffered here is, as indeed all explanations are, always open to discussion. Models are an important tool in the explanatory process, and therefore also an integral part of scientific theory.

In addition to models proper, there are other, simpler devices, such as diagrams and classification schemas, which may be used for description and prediction, but are not equally well suited for hypothesis generation and explanation (cf. Harré,

1960). Of these, I am particularly concerned with behavioural taxonomies, which I shall discuss below at some length. What is particularly relevant in this context is that there is a correspondence between hierarchical models and taxonomies; whereas the former may be used to explore fresh theoretical relations, the latter devices are used to represent 'reality' in terms that are different from those normally applied in its description. As was mentioned above, the borders between explanation and description are not always clearly demarcated, and I suspect that transgressions frequently occur where hierarchical models and taxonomies are concerned. As we shall see below, this may sometimes lead to problems. It is, therefore, desirable to keep in mind the distinction between the two types of structure. In order to emphasize this, I shall here refer to the models proper as 'explanatory models' and to those devices which are used as if they were models when they are really of the simpler type as 'descriptive models'. The latter models are probably often the precursors of models proper.

All models may be distinguished as being schematic descriptions and reconstructions of the things to be explained, and within this frame, two distinct types of explanatory models may be distinguished (cf. Harré, 1960). The first type is scale models built of the same kind of material but on a smaller scale than the thing modelled. This type of model may be used for description or directly in experiments of the processes under study. An extension of this former type is the representation in some detail on paper or some other medium of the essential parts of the thing modelled, where the representation assumes the same kind of material as the thing was originally constructed of. Maps and blueprints would belong here.

As an example of the first type of model we can take that of a car-engine, of which we do not just want to be able to say "This is what a car-engine looks like; this is the crankshaft; the crankshaft is joined to the pistons; the pistons move up and down inside the cylinders" etc. We also want to be able to say "When the fuel that has been injected into the combustion chambers explodes due to the ignition by an electric spark, the pressure created by the gases pushes down the pistons, and this movement is transferred to the crankshaft" etc. Furthermore, we may want to be able to predict the performance of such an engine under a variety of conditions, such as the piston being in different positions as the combustion occurs, and the effect this has on the performance. These contingencies may be simulated in the model, while it may not be convenient or even possible to observe them directly in the full-scale engine itself. And as we want to be able to examine all this without being distracted by the nuts and bolts, oil, dirt, and exhaust of a real engine, we may conveniently do it by the use of the model.

An example of the use of this first type of modelling procedure in behavioural science is when we have the behaviour of one organism represent the behaviour of another organism. The behaviour of the first organism is then also regarded as being simpler than that of the second. Thus, for example, we isolate newborn monkeys from their mothers, and then study how these simians' affective development is different from that of other

monkeys that are reared with their mothers. We then use the results to describe similar differential development in human babies, as well as to explain why the presence of certain factors in our early environment results in certain types of later development. There are, of course, other hypotheses and models also involved in this deductive process which will most probably be incorporated in a wider theoretical framework. But the example suffices to show the use of the first type of model as applied to behaviour.

The second type of model is in a way a further extension of the first type. Here, we have schematic descriptions of the processes and things modelled, not only in some other medium than the original, but also in terms of some different, somehow analogous process or thing. The representation of electricity as the flow of a liquid, or that of the atom as a miniature solar system are of this type.

Before going on to the discussion of some of the models of the second type which may be used for representing behaviour, a further definition of a few key concepts as well as some clarification of the basic processes involved in behaviour observation is necessary. I am here, as I mentioned earlier, particularly concerned with 'taxonomy' which is an essential concept in biological science, as well as the methods of its construction and its uses in the description of behaviour. To begin with, 'taxonomy' may be understood as the science of classifying organisms according to their morphological or behavioural properties, or 'traits', into classes containing more or less of some particular ones of these traits (cf. Sneath & Socal, 1973). This kind of classification is also known as 'Aristotelean systematization' (Harré, 1960). In non-numerical taxonomy the individuals or objects being classified are identified by the use of a 'key' which specifies the subset of the total set of traits that characterizes the unit to be classified (cf. e.g. King & Nichols, 1960). The key can also be represented as an explicit program composed of a series of subroutines within which specific questions are answered regarding the traits that an individual or an object must have in order to be placed within a specific class (Miller & Johnson-Laird, 1976).

'Taxonomy' may also be understood as the conceptual frame of such a classificatory process, i.e. a classification system of a particular kind, or an information structure, where the classes are related to each other by their degree of inclusion or number of traits shared. Thus, Miller and Johnson-Laird (1976, p. 282) state that "The taxonomy that derives from a general theory corresponds to what we have called the conceptual core; the key that is used to identify instances corresponds to an integrated set of schemata." In this latter sense, a taxonomy is often represented as a hierarchical system or (inverted) 'tree', where the 'hierarchy' or 'root' has all the traits defined for the system, while the lowest classes or 'leaves' are characterized by only one or a few of the traits.

Thus, a 'taxonomy' is alternatively defined as a general method of classification; the ordered result of the application of this method to a body of data; or the classification schema

to which the data are referred, together with a set of rules for ordering the set of data objects into a system. In the present thesis I am, in particular, concerned with taxonomies as defined according to the third alternative, which I shall refer to as 'a priori taxonomies', and according to the second alternative, which I shall refer to as 'a posteriori taxonomies' when the need arises to separate them conceptually.

A taxonomic structure is hierarchical, and the number of levels in the hierarchy, the depth of the tree, may vary. Important things to remember are, firstly, that the objects classified (in Aristotelian systematization) are only associated with the lowest hierarchical level, the leaves of the tree, and secondly, that the classes at all levels of the hierarchy are merely abstractions. A hierarchy, on the other hand, may be a taxonomy, or it may be a different kind of structure, not primarily intended for classification, as will be discussed below. As long as the taxonomy is employed for the classification of conceptually like things, it is useful; but it is of little use for classifying things that belong in different kinds of categories. To exemplify this I shall take a simple question concerning the identity of a behavioural unit that might arise during observation of some organism's social behaviour: "Is this a threat or is it a raised eyebrow?". This question may be profitably asked if 'threat' has an independent and clear definition in terms of morphology, or if there is a category in the taxonomy such that a 'raised eyebrow' is an instance of non-'threat'. Otherwise, 'threat' will be understood as a functionally defined item, one that may have several, different morphologically defined extensions and a single class of consequences; while 'raised eyebrow' will be understood as a bodily movement with one morphological extension and no definite consequences. In which case the comparison would not be meaningful, and, if made, would only lead to confusion.

Explanations.

The consequences for the explanation and general understanding of behavioural phenomena of the conflation of morphological, functional, and other ethological categories have been discussed by Purton (1978). In general, the conceptual muddle that results from category conflation of this type is considerable, especially as descriptions may be mistaken for explanations, and the investigator may then try to avail himself of such conceptual tools as hypothetical deduction which is allowable within a well defined theory. A clear example of description mistaken for explanation is that given of the soporific qualities of opium, reputedly popular in medieval medicine: "Opium makes people sleep because it is endowed with 'vis dormativa'". This constitutes an 'explanation' because it apparently refers to something outside the immediate context of the behavioural phenomenon of 'falling asleep'. But as long as we cannot identify this 'vis dormativa' (i.e. sleep-inducing power) in any other way than by observing people falling asleep after consuming opium, the proposition is a tautology: "Opium makes people fall asleep because people fall asleep after having consumed opium"! It is just this one, analytical fact that remains, and it is a description of a change in

behavioural state. Similarly, if we propose that a 'threat' display of one organism during a social encounter has the effect of making another organism take to its heels, then this constitutes an explanation of the happening if we have previously defined 'treat display' in terms other than 'makes organisms flee', specifically in morphological terms. Furthermore, this is a different type of explanation of behaviour in terms of function than that in terms of survival. (5)

The main distinctive feature of behaviour observation is sometimes taken to be that its results are descriptive in character. This may then be contrasted with experimental studies of behaviour whose results are often taken to explain certain phenomena. However, as we have already seen, the difference between observation and experiment does not lie here, but rather in that the two types of study tend to employ different types of classification, the one type of study morphological or functional, and the other causal classification. Both types of study encompass both description and explanation, but the way these are employed differs. Thus, observation of nature is likely to stress the importance of description, whereas in an experiment, at least the preliminary classification and description of the field of study will be assumed to have taken place.

If one were to attempt a summing-up of the respective advantages of observation and experiment, it might be something like this: In a behavioural experiment which employs causal explanation of the results, we are obliged to establish a dichotomy of classification in terms of 'cause' and 'effect', and the phenomena studied are divided into those two classes, while everything else is 'controlled' or neutralized. The 'cause-effect' dichotomy may be regarded as a way for us of increasing the redundancy in our cognitive input, and thus establishing clearer relations in our conceptual world. In behaviour observation, our aims will be similar, but the way we reach them will be somewhat different. In this case the classes that we establish at the beginning of the study are not two but many, and the dynamic relations between them are worked out at the end of the study. Furthermore, these relations are not dichotomous but continuous; they may be 'positive' (facilitatory) or 'negative' (inhibitory) (cf. (9)), and these qualities will be exhibited with varying degrees of probability. This multitude of possibilities for classification of the dynamic relations in the behavioural stream are a far cry from the cause-effect dichotomy. The result is that, in behaviour observation, both the flexibility of the possible interpretations and the information load on the investigator are increased, relative to what would be the result in an experimental enquiry. Which may be judged to be good or bad.

Some models of behaviour.

At this point I want to examine a new version of the model of escape behaviour shown previously (Figure 2). My reason for proposing this new version, which is shown in Figure 3, is to illustrate how a very simple (minimal) model may be used to combine several powerful concepts, and thus promote understanding of otherwise complex phenomena. At the same time I want to pave the way for the further development of the general arguments that I pursue here. I have altered the labels in the 'bubbles' in the model so as to give a new meaning to the processes involved, while the framework within which this happens remains the same. Thus, I have made the model wholly general by having it refer to all behaviour, instead of just the escape behaviour of a sparrow.

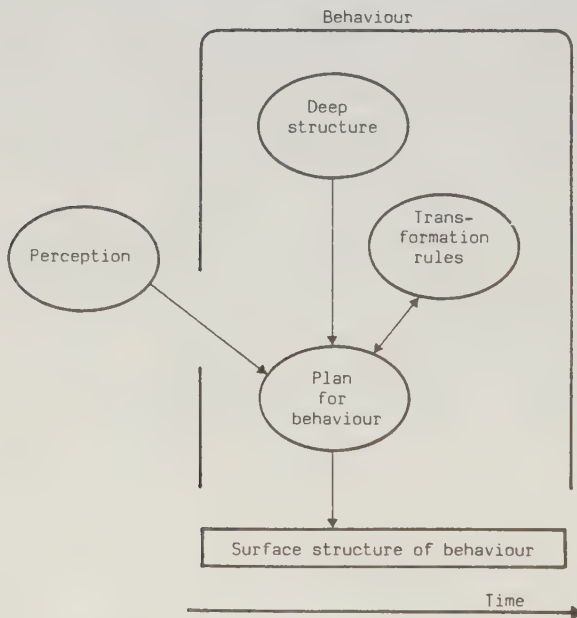


Figure 3. A general model for behaviour. The model is expressed in terms of generative rules for behaviour which are the basis for a Plan of action. The assumed relation between units in the model may be characterized as 'influences'.

Where there was previously the awareness of a hawk, there is now perception in general; and inside the general domain of behaviour in the model I have substituted terms borrowed from two of the theories described in a previous section, viz. those of Chomsky (1957) and Miller et al. (1960). In this new version of the model, I label the bubble formerly called 'innate' as 'deep structure' of behaviour and what was previously called 'learned' as 'transformation rules'; and I label the bubble previously containing the relatively unspecified 'behaviour base' as 'Plan

of behaviour'; and the 'observed behaviour sequence' I now give the label 'surface structure of behaviour'. What this accomplishes is, firstly, to relieve the model of many of the restrictions that formerly encumbered it, and secondly, to open it to the possibilities entailed in the theories wherefrom the new terms were taken. Thus, the deep structure is what exists as a basis for all behaviour, its 'a priori knowledge' which may be the result of many factors, including genetic information; the transformation rules, which are assumed to be mainly learned, act on selected parts of this structure in accordance with a super-ordinate Plan which determines how the possible behavioural alternatives are coordinated with the incoming information so as to result in the observable stream of behaviour, the surface structure. This set-up allows for a considerably enlarged choice of alternatives for research within each of the domains specified in the 'bubbles' as well between them.

The Plan, as I conceive of it here, may be seen to take on many of the functions that were previously attributed to motivation. Thus, the Plan directs behaviour, as it contains a programmatic description of the steps that must be taken in order to accomplish the various sub-goals specified in it; and the Plan also provides the framework for classifying the behaviour elements observed, as each element of behaviour produced by the organism is specified in the Plan. The activation part of motivation may also be incorporated in the Plan, for instance in the form of a Boolean variable, or 'flag'; the flag would be hoisted when the Plan was set in motion, and as long as the flag was up, this particular Plan would be followed and the on-going behaviour would continue; but when the flag was lowered, as a result of the comparison to the value of some external variable or one created as a result of the operation of the Plan, the on-going behavioural process would stop, and another Plan would be set in motion.

In this way, many of the important attributes of motivation can be transferred to the Plan, and this has the advantage of laying them open to scrutiny. All that now remains of motivation is the general energy component itself, the raw force that drives the organism. But stripped of its specific attributes, the concept of motivation has no more meaning than electricity or heat which have to be added to some medium or conductor to be 'observable' or understood. 'Motivation' would then be equivalent to Clark Hull's intervening variable, 'I', a parameter in a behavioural formula (cf. Hull, 1943).

It should be clear that by manipulating the models available for description and explanation of behaviour, it is possible to achieve a better understanding of the processes involved here. I shall now go on to examine Tinbergen's (1950) model of motivated behaviour, and I hope to be able to demonstrate how many of the concepts which I have introduced and discussed above will be applicable in the analysis of this model. Tinbergen's model (shown in Figure 4 with a number of annotations) is hierarchic, and the hierarchy may be shown to be the 'reproductive motivation' of a stickleback (here the 'major instinct'). The stickleback's behaviour is presented as being the function of hierarchically organised centres, the behaviour portrayed as being organised

'from the top down' (cf. Leonard, 1984), i.e. the process which eventually appears as observable behaviour of the organism is set in motion by forces emanating from the hierarchy and moving downwards through the many levels of organisation of the hierarchy. The behavioural energy is shunted down by the action of block-removing mechanisms (I.R.M's), through gates associated with successively more specific action, until at last it is actualized in the motor units of the effectors.

Tinbergen's model is important for the present discussion as it raises several questions about the use in behavioural science of models and other theoretical constructs, such as that of motivation. Another, relevant question concerns the notion of hierarchy which gives shape to the model: Is it a 'true' hierarchy? Both the question of motivation and that of hierarchy are related to a third one about the allowable relations between the components of the model. These and other questions occasioned by this example will be discussed further below.

It is interesting to note that in Tinbergen's model, the units of behaviour represented above the horizontal divide are both molar and functional, while those below the line are molecular and morphologically defined. In general, these pairs of attributes do not exist independently, but characterize the same types of units, although the respective terminologies are applicable in different contexts (however, cf. Moore, 1983, for a different line of reasoning). It would, furthermore, seem that these different sets of attributes correspond to what Hamlyn (1953) has referred to as 'behaviour' etc. and 'movement' etc., respectively, and what Purton (1978) defines as 'action' and 'movement', respectively.

In a comprehensive theory of behaviour, both types of categories of behaviour units, functional and morphological, must be considered. However, an inability to keep the different types of categories apart seems to ail theorists of behaviour, and this sometimes leads to confusing results. A solution to the problem may be attempted by discouraging or forbidding the use of the one or the other type of category in behavioural explanation, with the claim that one type is 'inferior' to the other or 'not the proper subject matter' of a behavioural discipline (e.g. King & Nichols, 1960; Skinner, 1953). While one may profitably restrict one's sphere of discussion in a particular context, depending on the level of discourse and the problem in hand, prohibition in this as in other spheres of human endeavour is never an optimal solution.

Purton (1978) has pointed out that the conflation of functional and morphological categories of behaviour may lead to serious problems in ethological theory. In Tinbergen's model, both these types of categories are explicitly included as parts of the same model of behaviour. Superficially, it would seem that the inclusion of both the types does not have any negative effect, as they are qualified as being subjects to different types of interrelationships. But this sort of hybridization is not without problems, and complications do arise. Thus, it seems inevitable that users of the model actually conflate the categories of relations between the units in the model, as the dif-

ferent levels are held together by the very relations which are defined by the energizing aspect of the major instinct. Tinbergen does not specify explicitly, either, the nature of the changeover from inhibitive to co-ordinative interrelationships between units in the model, and on the whole, the structure is descriptive of the types of behavioural events occurring within a period in an organism's life, rather than determinant of what will happen at any sequential point in time during this period.

Motivated behaviour

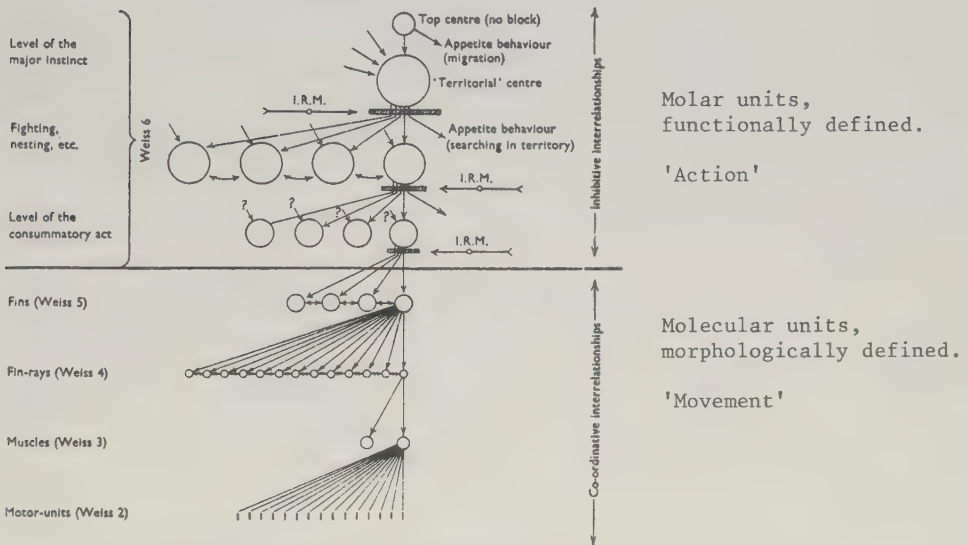


Fig. 1. Symbolic representation of the hierarchical organization of 'centres' playing a part in instinctive behaviour. Explanation in text.

Figure 4. Tinbergen's (1950) model of motivated behaviour. The behaviour units above the solid line in the middle of the hierarchy may be characterized as 'molar' and those below as 'molecular' (cf. Moore, 1983), or alternatively as 'actions' and 'movements', respectively (cf. Purton, 1978).

Models employing some psychological or motive force are the rule rather than the exception in theories of behaviour. It seems that it is often difficult to produce an acceptable explanation for why organisms behave in any particular manner, if one does not have recourse to some hypothetical force or entity, which is then seen as 'pushing' forth the behaviour. This entity may be anything from an outside influence, a physical or non-physical being (: "He made me do it!"), to a 'local resident' entity, a homunculus or a psychic force, a 'ghost in the machine' (Ryle, 1949; cf. Peters, 1958, for an extended discussion of these concepts). In ethology we have, for example, Lorenz' (1950) 'psychohydraulic' model of instinctive behaviour which is

capable of explaining many of the behavioural phenomena attributed to instinct, such as 'vacuum reactions' and 'displacement activity' (cf. also Armstrong, 1950, and Tinbergen's, 1951, theory of instinct for a development of the concept).

However, in the case of displacement activity, the same phenomena would, be at least equally well explained by a probabilistic threshold activation model, such as that proposed by Dawkins (1969) to explain the pecking behaviour of chicks. The only assumptions made in this model concerning the activating energy and its behavioural correlates, are that the amplitude of the activation increases and decreases in an irregular rhythm, and that an increase in activation brings about an increase in the behavioural choices that the chicks have. Dawkins and Dawkins (1974) presented a generalized version of this model, where, by a simple interchange of logical relations, it is elegantly extended to explain also the courtship behaviour of bananaflies, as studied by Bastock and Manning (1955). They also present a mathematical analogue of the model, from which predictions about behavioural choices may be deduced.

Hierarchies.

Hierarchical classification is a sound and universally applicable method for organising information for easy access. Traditionally, classification in both botany and structural zoology is characterized in terms of kingdoms, phyla, classes, orders, families, genera, and species; individual organisms are ordered within species, the species within genera, the genera within families, and so on. Because of their generality, these principles of systematization have been adopted by many other scientific disciplines, although the divisions of systematic biology are not retained elsewhere. The instrument of this activity, the hierarchical frame on which the specific taxonomic system is draped, is an instance of the class of models which was referred to previously as 'descriptive'. It seems plausible to argue that all hierarchical schemes, whatever their uses, are derived from taxonomies, but when used to represent behaviour, are given extended connotations in terms of energy flow, control etc. All in all, this type of systematization seems to be a basic human way of representing things cognitively.

Dawkins (1976) has presented an interesting analysis of the possible uses of hierarchical models for describing and explaining organismic behaviour. As he points out (p. 10) "the branching hierarchy idea has found its way into biology many times"; it "is the basis of both Linnéan and post-Darwinean taxonomy"; and has "a long history in human and animal psychology, predating the more familiar ethological ideas". Concerning the suitability of hierarchical models for organismic behaviour, Dawkins (p. 19) states that "Hierarchy seems to fulfil a major requirement of good general candidate principle for the organisation of behaviour; it makes functional and logical sense".

Dawkins also discusses several important aspects of hierarchies in general. Thus, he defines a hierarchy generally as "a set of elements with a relation", where the basic relation

between the elements is 'is boss of'. He then develops the notion of 'true hierarchies': Given elements A and B, "A is superior to B when either A is boss of B or A is boss of an element which is superior to B" (p. 9). Furthermore, a "hierarchy is a set of relations which satisfies: (i) There is no element in the set which is superior to itself, and (ii) there is one element in the set, to be called the "hierarch", which is superior to all other elements in the set" (p. 10). By applying these general principles to different sets of elements, and at the same time transforming the basic relation 'is boss of' to more specific ones, we get such structures as a family tree ('is an ancestor of'), an oak tree ('is attached to'), and the army ('gives orders to'), to name but a few.

Both Nelson (1973) and Dawkins (1976) distinguish at least two types of hierarchies which are used for representing behaviour. Thus, Nelson (pp. 312-313) distinguishes hierarchies of 'embedment' and of 'connection'. According to him, the former type contains temporal relations between the elements represented in it, and Nelson takes Tinbergen's model of motivated behaviour as an example of this. He points out that hierarchies of this type may also be found in other scientific disciplines, e.g. "the structural hierarchy of matter". Nelson proposes that the latter type of hierarchy, that of connection, is the type found in the nervous systems of organisms, as well as, for example, in "the ecclesiastical chain-of-command".

Dawkins (p. 14) makes a similar distinction between types of hierarchies to that which Nelson makes. However, he proposes that in this connection "embedment is largely equivalent to classification. ... A hierarchy of classification is one in which 'is boss of' has some such meaning as 'contains' or 'includes'", where the "inferior elements actually make up the parts of the higher elements". Thus, Dawkins' definition of a hierarchy of embedment or classification is similar to that which I presented above for a 'taxonomy'. Dawkins' definition of hierarchy of connection is similar to that given by Nelson. Dawkins also introduces a third type, 'hierarchy of decisions', which may be subsumed under 'hierarchy of connection' according to Dawkins' earlier definition of that type, as both these types of hierarchies are connected internally by a kind of 'chain-of-command'. Hierarchies of decision, as defined by Dawkins, include at their nodes not single elements but sets of elements together with weighted decision procedures. This type of hierarchy may be seen to have a lot in common with the TOTES of Miller et al. (1960), the 'heterarchies' of information networks discussed by Winston (1977), and Nelson's (1973) notion of 'distributed control' in neural networks. All of these behaviour structures constitute hierarchies of complex elements which themselves are not hierarchies but rather local information networks, where any sub-element has a reciprocal relation to other sub-elements within its sphere of influence.

As Nelson (1973) has pointed out, it is not without problems to postulate a pure hierarchical control of behaviour, from the hierarchical motive force to the observed sequence of behavioural events. What we actually register when we systematically observe behaviour is the predefined elements of the behaviour catalogue,

and these elements often, but not always, turn out to be grouped in such a way as would be expected in a hierarchically controlled system. And as Miller et al. and Dawkins have so persuasively demonstrated, it is often possible to fit plausible hierarchical models to the surface structure of behaviour, given the addition of some intervening processes to these models. However, there may be some problems associated with this practice, and, for example, Miller et al. (p. 78) point out in connection with Tinbergen's model of motivated behaviour that "Not until Tinbergen's description reaches the level of the consummatory act does it take on the hierarchically organized sequence characteristic of a Plan. Thus we are led to think of relatively discrete, stereotyped, innate Plans for organizing actions into a consummatory act, but those acts are themselves ordered in time by some other mechanism". Similarly, Nelson argues that many different organising principles may be found in nervous systems, and only a minority of them are strictly hierarchical. But when it comes to the translation of some of these principles into behaviour, we may in fact often get what appears to be a hierarchical organisation. What the arguments of both Miller et al. and Nelson amount to is that, whatever the underlying structure of behaviour, the surface structure will often be compatible with a hierarchical model.

When we talk about the structure of behaviour, it is necessary to remember that the surface structure is always sequential, and that the hierarchical structure is inferred from observed sequences. However, it is hardly likely that the organisation which we may find in the underlying structure is more than analogously of the same form as the temporal groupings which we infer from the surface structure. Even if the a posteriori groupings of the behaviour elements have a structure where Plans within Plans within Plans etc. may be discerned, it is not probable that more than a few extended sequences of behaviour would be ready to be executed at a moment's notice. Yet, many shorter sequences or Plans for movement sequences are likely to be stored within any particular organism. These plans for behavioural execution would be carried out as the need arose, they would often be internally flexible, and their surface composition would most likely be generated by at least partly learned transformation rules. This hypothesis is supported by a fair amount of evidence from different sources, such as that emerging from the experiments by Restle (1970) on the learning of sequences of light-codes by human subjects, and the studies by Dawkins (1969) of the pecking behaviour of chicks. The results from these and other, similar studies indicate that there is a marked preference among various higher organisms for the learning of material that is arranged in 'chunks' rather than 'bits' (cf. Miller, 1956), as well as a clear tendency to produce sequences of behaviour that demonstrate organised 'chunking' properties. These sequences may be the grammatical sentences of human speakers or the courting behaviour of pigeons. But not only do these studies indicate that behaviour tends to come in chunks, but that the chunks themselves tend to be organised in chunks, which is characteristic of the higher and lower order contingencies of hierarchical structures on many different levels.

Relations.

In the analysis presented so far of behavioural hierarchy, I have not been specifically concerned with those sequential properties which I defined previously as the 'static' and the 'dynamic' structure of behaviour, respectively. However, analyses pertinent to these sequential properties may profitably be applied to behavioural hierarchies which are, as I have indicated, abstractions from observed sequences of behaviour. We are then in a position to see that there is a degree of correspondence between the static structure of behaviour and the type of hierarchy that Dawkins refers to as that of classification. Similarly, the dynamic structure may be seen to correspond to hierarchies of connection. And, following my earlier line of reasoning, hierarchies of classification may be identified as being equivalent to taxonomies which, in turn, are seen to be descriptive models; while hierarchies of connection would seem to have a lot in common with explanatory models. Lastly, drawing a tentative conclusion from this deductive exercise, it would seem that what characterizes descriptive models of behaviour is a static structure, while a dynamic structure is characteristic of explanatory models of behaviour.

It is necessary at this point to clarify further the concepts of 'static' and 'dynamic' structure. I stated earlier that the static structure of behaviour corresponds to the sequence of elements itself, while the dynamic structure corresponds to the mutual relations between the elements. However, the relative placements of the elements in the sequence may also be seen to constitute a relation between them, e.g. a 'locative' relation (cf. below). The nature of this type of relation becomes clearer when the sequence characterized as a static structure is transformed into a taxonomy, when similar relations between the previously established groups of elements may also emerge. These relations I shall refer to as 'static relations'. Similarly, I shall refer to the relations existing between elements in the dynamic behavioural structure, as well as the relations emergent through transformation of the dynamic structure into a hierarchy, as 'dynamic relations'. Examples of these two types of relations as applied to both morphologically and functionally defined behaviour units are shown in Table 1.

Miller and Johnson-Laird (1976) have examined the different relations between categories in conceptual systems which may result in hierarchical structures have been. In particular, they consider three types of relation between concepts which have this quality: a) Locative inclusion, expressed commonly as 'v is in w', and in predicate calculus terms as $(IN(v,w))$; b) part-whole relation, expressed as 'v is a proper part of w', and $(PPRT(v,w))$; and c) class inclusion, expressed as 'v is a (kind of) w', and $(ISA(v,w))$. All these relations are both asymmetrical and transitive (cf. e.g. Hughes & Londey, 1965), may all imply hierarchical relations, and are structurally similar in that they may be translated into Euler circles. The first of the three relations is the simplest one, and possibly the precursor of the other two, while the last one is somewhat different from the others in that it may imply both class inclusion and class membership. The difference between the second and third of the

Table 1. A matrix of static/dynamic relations by morphological/ functionally defined elements. Any of the 4 combinations may occur in a behaviour observation. The examples of relations and elements shown in the cells are in calculus notation.

Abbreviations: OCC: 'occurs in the next temporal interval'; FAC: 'facilitates the occurrence of the next unit'; REY: 'raised eyebrow'; RUL: 'rapid use of legs'; THR: 'threat'; FLI: 'flight'.

ELEMENTS				
		Morphological:	Functional:	
		RUL, REY	THR, FLI	
R				
E	STATIC:	(OCC(RUL,REY))	(OCC(THR,FLI))	
L	OCC			
A				
T				
I				
O	DYNAMIC:	(FAC(REY,RUL))	(FAC(THR,FLI))	
N	FAC			
S				

relations is further elaborated by Miller and Johnson-Laird in a discussion of 'hyponymy' and 'partonymy', where 'hyponymy' refers to "the relation of class inclusion between labels" (e.g. 'table' is a hyponym (subname) of 'furniture'), while 'partonymy' refers to the part-whole relation between labels (e.g. 'nose' is a partonym (part-name) of 'face') (pp. 241-242).

If we examine the relations of hyponymy and partonymy more closely, we can see a considerable resemblance to the relations defined above as 'static'. Furthermore, both result in proper taxonomies, although the respective taxonomies are of different types. It should be noted that, according to Dawkins, a taxonomy is a hierarchy in the strictest sense, as are also dynamic structures which are governed by 'is boss of' relations. It is also possible to ascertain that dynamic relations are neither hyponymous nor partonymous, but represent instead a 'transfer of influence' from one part of the model to another, and the units in the hierarchy from which influence is passed cannot be regarded as in any way subsuming the units to which the influence is transferred. The dynamic relation, in its most general sense, would sometimes exhibit symmetrical or transitive properties and sometimes not, and thus also be both non-symmetrical and non-transitive (cf. Hughes & Lodney, 1965); any unit would then be capable of transferring influence to any other unit within its sphere, and the influence might or might not be transferred to other units than the immediately neighbouring ones. And it would then not result in a hierarchy in the strictest sense as defined by Dawkins (1976). Hierarchical structures which include dynamic relations are often explanatory in character, whereas taxonomies are descriptive. However, one must not let the common structure tempt one into confusing the relations within the two.

Before concluding this discussion of the relations found in models of behaviour, I shall summarize the main points made so far. I maintain that hierarchical structures may equally well be joined by either of the two basic types of relations, the static and the dynamic, and the result in the two cases is descriptive and explanatory models, respectively. Furthermore, static relations are asymmetrical and transitive and result as a rule in true hierarchies, whereas the dynamic relations tend often to be non-symmetrical and non-transitive, and result only sometimes in true hierarchies. There are three main types of static relations, locative inclusion, partonymy, and hyponymy, all of which result in taxonomies which are also 'true' hierarchies. There is, at the moment, no such definite grouping among the dynamic relations. However, I should like to suggest here 'causal' relations and 'effect' relations as two such types, for reasons that I shall shortly explain.

I have previously talked about the 'causal framework' in which units of behaviour are defined according to their causes. This is appropriate when one is discussing such general categories of experimental variables as 'stimuli' and 'responses'. But a discussion within the general framework of the ethological observation approach will require that we separate the behaviour units from the relations that join them, in this case the causal relation. It should be fairly obvious from the foregoing discussion that the causal relations may be subsumed under the more general ones of dynamic relations as a special case. Thus, to say that for two events, A and B, there exists a causal relation between them such that 'A is the cause of B', or (CAUSE(A,B)), is to indicate that something has been transferred from A to B, a force, an influence, tendency, state etc. Moreover, this relation is asymmetrical and intransitive, as for these units - (CAUSE(B,A)) is not true, and also, for another pair of units, B and C, where (CAUSE(B,C)) is true, (CAUSE(A,C)) is not true. And, as with other dynamic relations, the units to which the causal relation is applied may be either morphologically or functionally defined.

I also wish to subsume under the general dynamic relation an 'effect relation'. Thus we can say that 'B is the effect of A', or (EFFECT(B,A)), which, analogously to the causal relation, would indicate that something was transferred to B from A. This relation might then be said to stand in a 'converse' relation to the causal relation, in the same way as 'is the son of' stands in a 'converse' relation to 'is the father of'. Another relation which I do not explicitly include here is the relation defining biological function, (FUNCTION(B,A)), which is used to define the behavioural elements which fall in one of the types of categories used in ethology (6).

Uses and abuses of behaviour models.

There are most likely many and fundamentally different reasons why a dispute over behavioural structure may arise between theorists. As there will be at that stage of theoretical development some implicit or explicit models of behaviour, I believe that three main reasons for confusion, resulting from the use of the

models, may be isolated. Thus, one may a) attempt to overburden a perfectly good model with explanatory demands, b) confuse the explanatory and descriptive aspects of a model, and c) expect the model to have a physical counterpart in 'reality'.

I discussed above how the relations found in different hierarchical systems representing behaviour may be shown to be of basically two types, viz. static and dynamic, and each of these types may be used to link morphologically or functionally defined elements within a model. This can, for example, be seen clearly in Tinbergen's model (Figure 4), within which both types of elements exist, functionally defined elements above the line in the middle, and morphologically defined elements below it. As may be recalled, the dynamic hierarchical relations are more general than the static ones in that they are sometimes transitive and sometimes not, and sometimes symmetrical and sometimes not; whereas the static relations are always asymmetrical and transitive. Thus, the only relations applicable to the whole of Tinbergen's model must specifically have these two attributes.

We have previously noted that, in the upper part of Tinbergen's model, motivational energy passes from centre to centre, guided by the action of sign stimuli and I.R.M.s. The passage from the level of the major instinct down to the 'level of the consummatory act' parallels the physical migration of the stickleback and its reproductive behaviour within a chosen territory. The relation between the centres in the upper part is clearly dynamic, and it may be inferred from Tinbergen's paper (1950, p. 307) that the relation in this part of the model is that of 'control'. Thus, while the model corresponds to what Dawkins has defined as a 'true hierarchy', it is not a descriptive model but rather explanatory in character. And as each 'centre' may be seen to be a kind of shorthand for a whole behaviour segment or a process which is set in motion by the instinctive energy, the upper part of the model is, in fact, similar to a hierarchy of plans or decisions.

In contrast to this, the lower part of Tinbergen's model may be seen to be a partonymic taxonomy, in which motor units branch out into smaller elements. Here, the same relations do not apply as in the upper part, and in fact, Tinbergen indicates explicitly that the two parts of the model are governed by different 'inter-relationships', 'inhibitive' in the upper part, but 'co-ordinative' in the lower. This means that in the upper part, any path down from the 'top centre' is exclusive of any other path, while the muscle units in the lower part are co-ordinated in the execution of any (consummatory) act. It is only at the middle level of acts that proper Plans and temporal groups of kindred activities may be discerned; and it is to this level that all other parts of the model must be related.

It seems that Tinbergen has borrowed the taxonomic frame from general biology, and placed in it behavioural units of different kinds (the two parts). But he has also endowed it with a directed energy flow, implying a relation between the units which is dynamic, asymmetrical and intransitive, and which may be characterized as 'control'. However, one of the consequences of having a motivational energy 'cascading' through the model, from the top

to the bottom is that the whole model is liable to be seen as governed by this relation. But as only a part of the model is dynamic, and the same relations between units are not applicable throughout, imposing motivational energy-flow on the whole model overburdens it, and its conceptual frame collapses.

Miller et al.'s (1960) suggestion that the consummatory acts enjoy a special status in Tinbergen's model provides a clue to how the model may be restructured. A closer look at the level of the consummatory acts reveals that they also enjoy the special status of being either morphologically or functionally defined. Thus a particular consummatory act may be one of several more or less similar behaviour patterns which all serve the same end; or it may be a fairly invariant sequence of motor units. In the latter case it is possible to state that the unit is composed of a limited number of motor elements, whereas in the former case, such a statement would hardly be tenable. Therefore, if we want to consider Tinbergen's model as dynamic, the part below the level of the consummatory acts must be left out, and the result would be a single structure where the major instinct was the hierarchy and the consummatory acts were at the lowest level. On the other hand, if Tinbergen's model is to be considered as static, the part above the consummatory acts must be left out, and this results in a set of related hierarchies where in each the consummatory act is the hierarchy and the lower levels consist of successively smaller effector units.

Hinde (1956,1960) has previously critically discussed Tinbergen's hierarchical model, but from a somewhat different viewpoint. Thus, Hinde (1960) points out, within the framework of a more general discussion of various energy models of behaviour, that in spite of their "success in discussions of the behaviour of the whole animal", these models have "certain grave disadvantages. In particular, they arise from a confusion between the properties of physical and behavioural energy, and from attempts to explain multiple processes in terms of simple unitary mechanisms". And as regards the explanatory function of 'behavioural energy', Hinde concludes that "It seems doubtful whether an energy concept is in fact necessary at all" (p. 212). Huntingford (1984) has also pointed out with respect to the assumed 'accumulation' and 'flow' of energy in neural structures, as suggested by Tinbergen (1951) for his hierarchical model, that "we now know that the nervous system does not work in this way and certain aspects of the model are inconsistent with physiological knowledge and have been rejected for that reason" (p. 52). With regard to this last objection, I would maintain that an external inconsistency of this type may be of relatively minor importance, considering that models are always more or less inexact replicas of the things that they represent. Thus, the rejection of the model will depend primarily on its internal inconsistency, as well as the availability of better explanatory models, i.e. models which are both consistent with known facts and can be used to explain and predict behavioural happenings.

It was discussed above how the utility and cognitive economy of classification may be enhanced in various ways by collecting together classes which represent behavioural elements of a similar kind in the hierarchic frame of a taxonomy. But a taxonomy

is, by definition, primarily a descriptive device, and using it for explanatory purposes requires that we redefine the relations between the units at the various levels. Thus, the static relations of locative inclusion, paronymy, and hyponymy would have to be appropriately interchanged with that of dynamic transfer of influence.

In this context it may be desirable to specify explicitly the choices and alternatives available to an organism obeying some biological or social imperative. A lucid way of doing this is in an algorithm containing a series of binary choices, where the decision taken depends on some physiological or environmental attribute being present. An algorithm of this sort may also be translated into a binary tree with the choices being made at the nodes. One such algorithm relevant to the upper part of Tinbergen's model is shown in Table 2. Some of the choices as-

Table 2. An algorithm (Plan) representing some of the decisions that have to be made for the successful traversing of the upper part of Tinbergen's model of stickleback behaviour. For the $1 \dots i \dots N$ steps, there is an instruction $a(i)$ which directs the organism's behaviour to a new sub-tree which includes step (i) among its alternatives.

Step	Decision
------	----------

- | | |
|------|--|
| 1 | Is the reproductive motivational 'flag' up?
a: No
a1: Do unproductive things!
b: Yes
b1: Carry on at next step |
| 2 | Has a territory been found?
a: No
a2: Keep looking for a territory!
b: Yes
b2: Carry on at next step |
| 3 | Has a nest-site been found?
a: No
a3: Keep looking for a nest-site!
b: Yes
b3: Carry on at next step |
| 4 | Has a nest been built?
a: No
a4: Build a nest!
b: Yes
b4: Carry on at next step |
| 5 | Has a suitable female been found?
a: No
a5: Find a suitable female!
b: Yes
b5: Carry on at next step |
| etc. | |

sociated with one type of decision, i.e. the answer 'Yes', are shown, and a similar decision tree may be created for the 'No' choices. Each of the alternatives at the nodes of the tree is also capable of being broken down into a sub-tree, and in this way a molecular level of specificity may be attained.

The energy that flows between levels in Tinbergen's model is what is commonly known as a 'hypothetical construct', which is a property defined for the model and existing only within it, but which may possibly also have some functional parallel in 'reality'. Such constructs are useful devices in explanation and prediction, as long as one does not impute to them more 'reality' than what they can be given in the model. Of course, the hunting of the 'real' counterpart is a respectful and laudable quest, but automatically assuming a 'reality' for a hypothetical construct (a practice sometimes referred to as 'reification') may cause much mischief.

An example of this kind of device is the 'vis dormativa' discussed in a previous section, which was also shown to be an unnecessary concept, having little or no explanatory power. However, many such devices in psychology may have considerable utility, and may be used for predicting behaviour or performance in many different situations. One hypothetical construct used in psychology is 'intelligence', usually quantified as IQ. Other entities are such psychodynamic constructs as 'the Id', 'the Ego', and 'the Superego', or the concept of 'personality'. In general, these constructs are related to dispositions to behave in specific ways. Thus, a high IQ would indicate a tendency on the part of the individual having it to be able to perform various complex tasks that individuals of lesser intelligence would not be able to perform; a person having a destructive personality would tend to break things and disrupt harmonious goings-on; while in any given individual, the Id would manifest itself in selfish and wanton acts, the Ego in realistic and well adapted behaviour, while the behaviour mediated by the Superego would tend to be sublime and unworldly. That there is a neurophysiological basis for these sets of dispositions, most theorists will agree on; but few if any theorists would claim to be able to pinpoint the actual, physical counterparts of these behavioural qualities. A disposition is a descriptive property; it may be used to sum up effectively a whole group of phenomena, and may be correlated with other properties, both behavioural and others, in various ways. But a disposition may be endowed with an object quality and used as a hypothetical construct in a model of behaviour; in which case it may mistakenly acquire an explanatory function within the theoretical framework where it is used. This would, for instance, happen if one were to explain a person's impulsive behaviour in terms of its being a result of the influence of the Id rather than the Ego. The general consensus among theorists is that an explanation must add something new to the exposition in which it occurs, thereby making it more understandable, and this kind of 'explanation' of a phenomenon in terms of itself is, therefore, no explanation at all. I am in this context reminded of the anecdote in which a famous society lady once was asked the question "What is a rose?" To which she replied "A rose is a rose is a rose!". For me this answer is an excellent means of calling to mind the aesthetic impression of

the flower in question, whereas it does not tell me anything about a rose in general other than what I already knew.

Perceiving behaviour.

It was stated above that behaviour, as experienced by an observer, is the result of a perceptual process. During this process a particular structure is imposed on the behaviour by the observer, and the surface structure observed in accordance with it. This position is not in any way solipsistic, i.e. I do not maintain that there is not an external reality for observers to experience. On the contrary, my position is that any observer is confronted with a 'reality', but his representation of this 'reality' is the product of a complex perceptual process which is shaped by a variety of factors, both internal and external. In their relation to external 'reality', perceptual experiences range from apperceptions of a largely internal origin, such as dreams and hallucinations, to highly reliable perceptions of this 'reality', which may be verified by reference to other independent perceptions by the observer, or comparison with the perceptions of other observers of the same 'reality'. (7)

Similarly, individual observers' perception of behaviour is influenced by a variety of both internal and external factors. A hungry observer may notice articles of food more readily than a satiated observer, and may even perceive food where none is to be found. The same is true for other motivational states. Thus, a sexually motivated person will readily perceive a variety of objects as symbols for both male and female sexual organs, and be only too ready to perceive sexual allusions in the behaviour of other individuals. Many other factors also influence the way we perceive things and events. For example, the physical dimensions, spatial positions, and movements of objects each influence the way we perceive the other of these properties, as do also the context of the observation, the instructions given to the observers, and a multitude of other factors (cf. Briem, 1975). Thus ultimately, no perceptual property is independent of any other.

One line of investigation of behaviour perception is concerned with what is referred to as 'attribution', i.e. the inference by an observer of qualities and attributes then seen to belong to the persons or objects concerned. A school of thought specifically concerned with studying these phenomena is the one known as 'attribution theory' (cf. Heider, 1958). A famous example of the original research leading up to this theory was that by Heider and Simmel (1944), in which observers of a short cartoon film sequence spontaneously attributed emotions and intentions to geometrical shapes seen to move across the screen. Newtonson and his collaborators (cf. Newtonson, 1976) have studied the attribution of various, relatively abstract qualities to observed human behaviour, and the way in which different factors influence this process. In particular, they have studied how observers come to perceive certain movement sequences in the stream of behaviour as 'actions', as well as how the size of these sections of the behaviour stream varies under the influence of situational variables. Thus, "Behaviour is composed of coherent units with

beginnings and endings, and, in general, there is a consensus across perceivers as to where those beginnings and endings are" (Newtson et al., 1977, pp. 848-849), and furthermore, "actions are encoded by the selection of successive 'points of definition' in the behaviour stream. These points of definition, termed 'breakpoints', are the boundaries of action units. Each breakpoint indicates the perceiver's judgement of the point at which one action ends and a different one begins. Breakpoints appear to be selected in such a way that the information contained at successive breakpoints is sufficient to reconstruct and interpret the event that occurred during the interval in between them" (Newtson et al., 1978, p. 379). However, the objective basis of perceived actions is not so much the relatively invariant morphological changes in posture and motion seen in the behaviour stream as the way in which the observer interprets the actions involved, even if perceptual cues may influence the 'size' of the action units (cf. Newtson et al., 1978; Atkinson & Allen, 1983).

The results of the research carried out by Newtson and his collaborators point to similar conclusions as those of Miller (1956), viz. that the size of the unit of human perceptual and cognitive analysis tends to depend on its information content for the observer. Thus, an observer groups together into cognitive units or 'chunks' such elements ('bits') of the stream of behaviour as are intelligibly related to each other. These elements are then seen to fit into a cognitive 'schema' for the corresponding action (cf. Bartlett, 1932; Neisser, 1976), and may be recalled as a unit when the need arises. Similarly, the component elements of the chunks can be recalled as individual happenings or actions. The behaviour perceived may in this way be seen to be organised on different levels, where the action units perceived differ considerably in size. This may happen in accordance with the instructions given to the observer, after interruptions and unexpected happenings during observation, and as a result of the occurrence of various social and situational stimuli (cf. Newtson, 1973). It may be seen that observers are able both to break down their 'normal' action units into smaller units, and also to form 'larger than normal' action units if so instructed. One of the dynamic aspects of the action-perceptual process has been found to be that observers of an extended sequence of behaviour tend to segment action sequences into relatively small units initially, and then successively shift to larger action units as the observation progresses (Newtson, 1976).

From these observations we can infer that the process of perceptual-cognitive representation of happenings and objects is not just limited to the formation of elements and chunks. We may readily imagine that the chunks become chunked together into progressively larger chunks, and linked together into hierarchies and networks. Available evidence from cognitive psychology provides ample support for this notion (cf. e.g. Collins & Quillian, 1969; Miller & Johnson-Laird, 1976).

When we remember that there is, theoretically, an unlimited number of ways of dividing a behaviour sequence into its component elements, the concordance found in the division of sequences by observers into action units as demonstrated by Newtson and

his collaborators may seem remarkable. One may wonder whether this is the result of the sequences shown to the observers being 'composed' of just those particular actions which were observed, or if different observers do have a tendency to interpret similar movement configurations as the same actions. The answer probably contains a bit of both these possibilities: Newton's action sequences seem often to have been composed of a) a few predetermined and highly stylized actions, and b) actions which are common and probably easily recognized by the observers for what they were intended to be. What is particularly interesting about Newton's findings, in the present context, is not so much that there are 'actions' with 'breakpoints' between them, although this needs to be pointed out and analyzed in detail, as the finding that what constitutes an action in a particular behaviour sequence may or may not be the same in different contexts, for different observers, and at different times. It also seems remarkable that what constitutes an action for an observer can be predicted from the knowledge of a variety of factors; and furthermore, the resolution of the action units in the stream of behaviour has a hierarchical structure, depending again of the influence of various factors.

Perception and cognition.

The perceptual processes involved in the way we attribute 'actions' to movements sequences, as described above, appear to be of the same kind as those which we employ in our cognitive functioning in general. Many of these have been described by Miller and Johnson-Laird (1976). These authors discuss, among other things, both empirical evidence for the formation of hierarchical, cognitive taxonomies and propose some general structures to describe and further explain this evidence (pp. 237-301; cf. also above). An interesting extension of Miller and Johnson-Laird's theoretical discussion of conceptual hierarchies has been made by Tversky and Hemenway (1984). These investigators examine how different characteristics of 'natural' categories are linked to perceptual structure, and the role played by 'parts' in determining the 'basic' or preferred level of abstraction in cognitive taxonomies. A 'part' refers here to an object attribute by which a category is qualified. Categories are considered 'natural' or 'basic' a) if many of their attributes are grouped together in different languages (universal categories), and b) if they are especially informative i.e. depending on how many different attributes they have (cf. Rosch et al., 1976). Basic categories appear in general to be mutually exclusive. Tversky and Hemenway coin the term 'partonomy' which they contrast to 'taxonomy' on the basis of the different types of relations involved in the cognitive structures investigated by them. In their proposal, 'partonomy' has a meaning that corresponds to that of Miller and Johnson-Laird's 'paronymy', while 'taxonomy' has a similar meaning to that of 'hyponymy'. These terms, as well as Tversky and Hemenway usage of them, are unfortunate, which should be apparent from the discussion presented earlier, and also as 'taxonomy' then assumes a special meaning which is less general than the normal reference of this term.

Tversky and Hemenway speculate about the relations between function and structure in cognitive hierarchies. They propose that categories at both the super- and supra-ordinate levels in cognitive hierarchies are derived from the basic categories which are at an intermediate cognitive level. If we extend Tversky and Hemenway's line of reasoning in a general direction, we can see that basic categories appear to be based on observation and experience of 'reality', and that they are, therefore, synthetic; while both super- and supra-ordinate categories are derived from the basic categories by analysis. In addition to pointing out that some categories are more 'natural' and 'basic' than others, Tversky and Hemenway propose that these basic categories are characterized by both functional and morphological parts, while the super-ordinate categories are almost exclusively functional, and the supra-ordinate ones mainly morphological! This conclusion agrees quite well with my previous analysis of Tinbergen's (1950) model.

It is apparent that the natural way in which we organise our cognitive world in general is reflected in many of the models we construct of organismic behaviour, and the primary function of these models appears to be to retouch our picture of the world rather than to repaint it. So, what is the relation between the production of behaviour by an organism and our perception of this behaviour? When it is a question of human perception of human behaviour, we can at least expect there to be some sort of correspondence between production and perception. Some behaviour evinces a particularly intimate relation between these aspects, such as when two people, who share a common language, carry on a conversation. This reciprocal relation in human communication is not limited to its linguistic aspects, but may also be seen in the paralinguistic and non-verbal aspects of this mutual activity (cf. above). But even if the communicative behaviour rhythms cut across cultural and racial boundaries, the understanding of what is being transmitted tends to be more than a little limited when the common, learned, symbolic base for the communication is missing.

As we noted previously, there is also a deep structure for all organismic behaviour which we must also take into account. The reciprocal, human communicative rhythms would seem to be a part of this structure, and thus be what has sometimes be referred to as 'universals' (cf. Hockett, 1960; Chomsky, 1975, in particular Chapter 4). These universals are even more immediately apparent in the communication of non-human organisms, but are for human beings found to be operative in certain para-linguistic and non-verbal systems. Thus for example, Miron, (1961) was able to show that certain phonemes tended to carry meaning in syllables that were otherwise meaningless, and they were also able to show that this phenomenon existed independently of particular languages. Analogous studies have been carried out by Eibl-Eibesfeldt (1970) with respect to the communicative properties of facial behaviour, where he showed that similar facial expressions were used to convey similar emotions and intentions in a wide range of quite disparate cultures. The correspondence between facial expressions and emotions was first studied scientifically by Charles Darwin over a century ago (cf. Darwin, 1965) whose insightful

observations may be said to have laid the ground for much of the modern work in this field. More recently, these relations have also been studied intensively by Ekman and Friesen and their collaborators (e.g. Ekman & Friesen, 1969; Ekman, 1982). The phylogeny of facial expression in the primates has been studied by e.g. Chevalier-Skolnikoff (1973), and the ontogeny of meaningful facial expressions in human babies by Prechtel (1958), Wolff (1966), Nyström and his collaborators (e.g. Nyström, 1977), Oster (1978), and others. What these investigators have found is that from the very first moments of extra-uterine life, there exists in the human infant a capability to produce facial-muscular configurations which are readily perceived by human observers as meaningful. It is probable that these expressions subsequently evolve into the facial behaviour communication system that grown-up people are so adept at using. Neonatal communication in the other direction, i.e. from the adult to the newborn baby, has also been reliably shown to exist, for example in the neonatal interactional synchronization of bodily movement with adult speech (Condon & Sander, 1974), and quite a few newborn babies are able to imitate successfully some well defined adult facial expressions (e.g. Meltzoff & Moore, 1983). This shows, at the least, that the basic machinery for interpersonal communication exists already at birth for the human neonate. However, there would hardly be a question of any deeper understanding on the behalf of the receiver in this case, and the sign that the communication has been received consists here of an imitation of the structural properties of the message itself.

Imitation, as I have briefly described it above, is a primitive form of social understanding, but may well be the basis of empathy and the understanding of other people's emotions that is shown by many older children and adults. Although this is an important area of behaviour perception, I choose here only to refer to other investigators (e.g. Viborg, 1984; Bengtsson & Johnsson, 1986) for a further discussion of these phenomena. Other potentially interesting areas of behaviour perception, such as the qualitative attribution of 'beauty', 'goodness' etc, and the relation of these attributes to other behavioural parameters and motivation, will also be left out of the present discussion.

Reliability and validity in behaviour observation.

The reliability of the assessment of the elements occurring in a stream of behaviour is largely a function of observer agreement. Two types of agreement may be distinguished, **intra-observer** and **inter-observer agreement**. The first of these refers to how a given observer's judgement of what has taken place agrees with the structural and functional properties of the behavioural configuration on different occasions when the behaviour is observed. The likelihood of a judgement of 'sameness' of the elements of behaviour on any two occasions would then depend partly on the similarity of the outer conditions of the behavioural occurrences and the observation itself, and also on the internal consistency that exists in the observer's perceptions. The inter-observer agreement would be subject to very similar contingencies, although here one would expect the dissimilarities between the judgements to be greater due to the fact that judgements from

different observers are involved, which depend on different perceptual systems and different sets of assumptions about the identity of the things observed.

There are also other factors involved here, such as the amount of prior agreement among observers, their ability and experience with observation of the kind in question, their cultural and cognitive similarities, and so on. Thus, for example, the reliability found in behaviour observation studies where a limited and well defined set of behaviour elements is being used should be considerably greater than the reliability between observers in studies where the identity of the behaviour units is not established a priori by common consensus, as in the studies carried out by Newton and his collaborators. But even here the choice between units was seen not to be random, although the behavioural classes were less stringently defined. In general, the stricter the operational definition of the observation, the greater the reliability of the judgements.

The question of the validity of the observation of a sequence of behaviour is somewhat more complex than that of reliability. Several types of validity may be distinguished, all of which are, in one way or another, concerned with how well we are assessing the behaviour that we believe we are observing. (8) One important type of validity is that referred to as 'content validity', which refers specifically to the extent to which the behaviour categories used in the observation reflect the underlying structure of the behaviour being observed. In this case, we are confronted with the problem of what categories to select for describing a particular type of behaviour. For example, when we wish to study people's 'aggressive behaviour', we have to begin by making a series of such a priori decisions as whether we should only consider as aggressive behaviour any violent, physical contact between individuals, and what then should in this context be considered as a 'violent' contact; also, should the various degrees of severity of the clash between individuals be classified as different types of aggressive behaviour, and each assigned to a specific class?; and should gestures and verbal encounters of certain types be classified as 'aggressive'? In order to enhance this type of validity, the inclusiveness and overlap of the categories used must be specified. Once the behaviour catalogue, or taxonomy, has been defined, the observers have to be trained together to achieve maximum agreement.

A second type of validity is 'concurrent validity'. This refers to whether the category chosen to represent the observed behaviour is predictably related to other features of the immediate situation. Concurrent validity is similar to a third type called the 'predictive validity' of a behavioural category which refers to the extent to which it is significantly related to some past or future feature of the organism's situation when such a relation has been predicted. Both these types of validity are concerned with an outcome based on the observation of some category of behaviour, and may be considered as ways of quantifying the units of behaviour under observation. Thus, we may want to assess the relationship between the aggression of a male stickleback and the introduction into his immediate surroundings of a red-bellied stickleback-simulacrum, and the concurrent vali-

dity of our category for aggression would be seen from the reaction to the dummy. Similarly, the predictive validity of a threat display of one organism to another would be shown by the subsequent flight of the organism subjected to the display.

A fourth type is '**construct validity**' which refers to how far the outcome of a behaviour observation study reflects the relations between the hypothetical entities postulated in the investigator's model of the behaviour observed. If we look at Tinbergen's model (Figure 4), we can see that the construct validity would here depend, among other things, on how well it describes the actual sequence of units of stickleback behaviour that may be observed during a particular period of time in that organism's life. Any significant deviations of the observed behaviour from that predicted from the model would entail a need for modifications of the model in order to accommodate these deviations. The equivalence of behaviour elements that are classified as being of the same type might, for example, also be scrutinized, as this would determine the allowable tests to which one could subject the observational data.

Other aspects of reliability and validity may emerge during the planning and carrying out of an observational study, such as problems of representative sampling and observational control. But all in all, a careful attendance to those aspects of an investigation will increase the generality the results obtained, and the use to which they can be put.

Inferring underlying structure from observed behaviour streams.

I have previously discussed at some length the different types of categories by which behaviour and other phenomena, may be classified. Any of these types of categories, which I have referred to here as morphological, functional, and causal, may be used to represent sequences of behavioural patterns in either of the two ways which I referred to previously as the 'static' and 'dynamic' structure of behaviour, respectively. Some combinations of types of relation and type of category were shown in Table 1 (q.v.). Regarding these combinations, it is possible to argue that there exists a logical order between them such that in a full-scale observation study of the details of interrelations between these element pairs we would first investigate the general relation (OCC(REY,RUL)), then (FAC(REY,RUL)), then (OCC(THR,FLI)), and last (FAC(THR,FLI)). Thus, we would begin our study of this simplified behavioural situation by identifying the morphological configuration 'REY' and its frequency of occurrence relative to the configuration 'RUL' in the next temporal interval. Then, if we were able to ascertain that these configurations occurred frequently in the same relative positions in the stream of behaviour, we would be able to state that the one 'facilitates' the other (9). Behaviour patterns exhibiting the relations thus established can be named in accordance with their observed function (e.g. 'threat' and 'flight'), and the relative frequency of occurrence of the proposed relation observed in other situations. Lastly, the dynamic facilitation of other patterns postulated as having the same functions can now also be tested.

When we observe behaviour, we do not usually observe only a couple of behaviour elements, although this may, of course, be done when it is deemed necessary. At the very outset, we would probably not have many a priori conceptions about the relations between the units in a morphologically defined taxonomy, but after a sequential analysis we may derive clear dynamic relations between these units, and then establish an a posteriori dynamic structure of the behaviour. We might also define some set of behaviour elements functionally, and then in some later application simply wish to concatenate these units in a static structure without reference to their effect. Thus, there is no reason why change-overs from one particular relation between elements to another should not be permitted or even desirable.

The causal categorization has been shown to represent a special case of dynamic relation between behaviour elements. We tend often to think of the causal relation as dyadic, i.e. any cause has but one effect and vice versa. Thinking of the causal relation as both asymmetrical and intransitive simplifies experimental analysis considerably. The problem of how to describe behaviour sequences in this mode is then solved by representing them as 'chains' of behaviour units, where each previous event or 'stimulus' is seen as in some way the necessary, although not always the sufficient occasion for a following event or 'response' (cf. Skinner, 1961). It is also possible to represent behaviour as a sequence of responses without identifying their exact stimuli a priori. Thus, each unit can be seen as a 'response' to something, but what this something is will only be revealed after analysis of the data.

The method selected for observing the behaviour of some particular organism is dependent on what behavioural category type one is interested in, a decision which in turn may be dependent on such factors as which scientific discipline one has as the base of one's activities, and how one prefers to regard the world in general. Thus, a scientist who is specifically trained in microscopic analysis may be more prone to look for morphological relations in organismic behaviour than a scientist whose training has mainly included a study of the macroscopic influences at work in human societies. Habit, preference, and other observer characteristics may determine how big or small the observed units are or whether their relations are static or dynamic; but any attempt at comprehensively describing behaviour will see it as a sequence of units of some sort.

Sooner or later it will also be convenient to group together or systematize the units of classification, and the way we do this will be according to taxonomic principles. Generally, if one prefers to use many categories, the number of different units identified as belonging in each will tend to be small, and if one employs only a few categories, the number of units in each will be large. (10) The size of the unit employed for the description of behaviour and the kinds of choices involved here have been discussed by Altmann (1965), among others. Altmann employs the terms 'splitting' and 'lumping' for the decisions involved in when to include or bring together different units into the same

behaviour category, on the one hand, and when to use a larger number of smaller categories in the descriptive process, on the other.

The reason for limiting the field of study is obvious: The stream of behaviour is extremely variable, and the same behaviour constellation can only occur once, ever, the actors never performing more than once in any setting. In order to get round this difficulty, we classify what we see taking place before our eyes: A specific combination of physical occurrences is taken to be the same as another one, given that they share a number of previously specified characteristics, irrespective of whether the time, the place, or the actors have a common identity. By these means we establish order in the world.

The first phase of a behavioural study must be concerned with establishing a taxonomy of behaviour units. A taxonomy of this kind is often referred to as a 'catalogue' of behaviour, and the units in it may all be at the same, or at different levels. The 'level' of a unit is here intended to imply inclusion, and is also partly intended to signify the 'size' of the behavioural units under study, i.e. how large a proportion of an individual's total behaviour under a given set of circumstances is included in any of the categories (cf. Moore, 1983). Thus, given 'work-place behaviour' as the universe of discourse, 'delving' and 'spinning' would be subsumed by and on a lower level than 'work', while 'lounging' and 'playing' would be subsumed by and on a lower level than 'non-work'. Another way of establishing the levels of a behavioural taxonomy is to determine how 'gross' or 'fine' the motor activity or the actions are which are characterized as elements of the behaviour at a particular level. Then the levels of the units are determined in the first instance, not from their actual inclusiveness of one another, but from their potential inclusiveness. Given that the three units, 'non-aggression', 'hitting' and 'kicking', constitute a behaviour catalogue, 'non-aggression' can be seen to be on a higher level than 'hitting' and 'kicking', which are instances of the implicit category 'aggression' which is on the same level as 'non-aggression'.

A taxonomy of behaviour should preferably constitute an 'exhaustive' catalogue of elements of the behaviour of interest. It would then be expected to include as units all the behaviour patterns observed for the particular organism worth noting down, i.e. any observable behavioural occurrence will be capable of being placed in some category existing in the taxonomy. An explicit taxonomy is always necessary for a successful study of an individual or a group, and its establishment may be seen as an end in itself. In ethology the catalogue is sometimes called 'ethogram', and it is often understood that the behaviour elements are of a functional kind, such as may be referred to as 'acts' or 'actions'; that they tend to appear in invariant forms which are easily identified; and that the catalogue includes a large number of such units.

It is in the nature of ethological reasoning that ethological units, in the same way as anatomically defined organs, be seen in the same or similar form in all normal individuals of a species, and in the same individual on different occasions. These units

have sometimes been referred to as 'Gestalten' (cf. van Hoof, 1982). Tinbergen (1959) has laid down principles for identifying such units according to morphological criteria. When the different, consistent postural configurations that an animal may exhibit have been isolated, it is possible to investigate more closely the temporal relations between them. Thus, if we can ascertain that several of these configurations occur simultaneously with some regularity, then it is justifiable to state that these combinations also constitute 'natural units' of posture or behaviour for the organism. The interrelations of these higher- and lower-order units may then be investigated further, and eventually combined in a taxonomy governed by some static (most probably partonymic) relation between the units.

The rationale behind the choice of units in ethology is expressed by Lorenz (1965, p. 35) thus: "in any system whose function consists of the interaction of many parts, the least changeable are the best point of departure, because their properties appear most often as causes and least often as effects in the interaction that is to be studied." But the behaviour may be classified not only according to its function but also according to its morphology. Furthermore, the levels of these two modes of classification often differ, the morphological units often being at a lower level than the functional ones. (11) Units which stretch out further in time and space may also be regarded as including units at lower levels as components. If we take the functional units which constitute an ethogram to be on an intermediate level, then on a still higher level we might include units which can be characterized as 'roles' or 'attitudes', i.e. categories which include within them a number of related, functional motor patterns. On the lower level we then have single muscle movements or groups of movements which are primarily characterized by their morphology (structure) but with less definite function associated with them. This was illustrated previously with reference to Tinbergen's (1950) model of motivated behaviour.

Many different kinds of classification are possible, depending on the needs and intentions of a particular study. Thus, while ethological type of study often employs a large number of categories on an intermediate or low level, experimental studies of a traditional type tend to employ classification on a higher level, and to have quite a small number of behaviour categories. Thus, for example, people's behaviour may be divided into two categories, emotional vs. unemotional, neurotic vs. non-neurotic, aggressive vs. placid, and so on. This common practice makes for a simplified experimental design and easy statistical decisions. But the dichotomization of human attributes possibly also entails an obscuring of many potentially interesting observations, and there is a danger of a facile dismissal of important differences as we lump diverse behavioural units into 'simple' either/or categories. However, I certainly do not mean to imply that an experimental study of behaviour is not justified or appropriate: Both types of study, observation and experiment, are applicable to different problems and at different stages of a behavioural investigation.

The discussion above is important for the present thesis, as it illustrates the relevance of ethological theory to behaviour observation methodology in general. Here, the size of the units into which the behaviour under study is divided, as well as the levels of analysis and explanation, may constitute a problem for the investigator. But once these aspects have been decided on, they are to a large extent fixed throughout the study, and it is important that they should be determined satisfactorily early on. There is a practical limit to how fine a resolution one can have for behavioural units in an observational study, but any units small enough would have to be described as morphological, and possibly also as innate. The level of analysis would also be linked to the size of the unit chosen, and the subsequent explanatory devices are to some extent determined by the kinds of analysis done of the observed behaviour sequences. Consequently, an appropriate conceptual representation of the behavioural structure and the processes at issue, preferably in terms of an explicit model, should exist *a priori*.

A priori and a posteriori taxonomies.

In this context I want to discuss further two of the types of taxonomies used to give structure to the behaviour under study. The first, the 'a priori taxonomy', is the one that exists at the beginning of any observation, an assumed, 'naive' structure, imposed on the behaviour to be studied, without which a meaningful observation of the behaviour is hardly possible. The second, the 'a posteriori taxonomy', comes into being at the end of an observational study, when the data collected during the observation are analysed with numerical and non-numerical methods. It will hopefully be a more sophisticated product than the a priori taxonomy, but will in its turn eventually serve as an a priori taxonomy in later studies. These structures may be explicitly or implicitly hierarchic, i.e. they may be on many levels, or on only one level, such as many ethograms and behaviour catalogues are.

It is important that the classes of behaviour defined for an a priori taxonomy are not only exhaustive (cf. above), but also mutually exclusive (cf. Hutt & Hutt, 1970). Thus, they should not be allowed to overlap in such a way that certain elements may sometimes belong in one class and sometimes in another, as happens when two different elements are simultaneously used to represent the same configuration of movements found in the stream of behaviour under observation. This may then happen in at least two different ways: Either the two elements or classes could be of roughly the same type and inclusion or level, such as when a behavioural occurrence is sometimes classified as 'threat' and sometimes as 'playful gesture'; or the classes could differ in their inclusion and one of them subsumed under the other, such as when a behavioural occurrence is sometimes classed as 'threat' and sometimes as 'aggressive behaviour'. These types of non-exclusion may also be combined with category conflation in various ways, which then confounds the situation still further. Thus, a behaviour pattern sometimes classified as 'raised eyebrow' might at other times be classified variously as 'threat',

'playful gesture', 'body movement', 'mimicry' etc. It is also possible to conceive of some situation where all these labels have been defined so as to refer to distinct, non-overlapping behaviour patterns at the same level of abstraction; but the simultaneous use of such normally disparate units, although not confounding the observation in a formal sense, would probably confuse the observer and thereby reduce the reliability and validity of the results of the behaviour observation.

The mutual exclusiveness of categories stipulated here does not mean that it should be impossible for two different behaviour patterns to occur simultaneously and only one of them to be recorded. In fact, simultaneous occurrence of different behaviour elements is the rule rather than the exception, but by defining the a priori taxonomy in the appropriate manner, we can avoid this becoming a problem for registration. The stipulation of mutual exclusiveness is thus not intended to distort behavioural representation, but instead to ensure correct and valid registration of the behaviour observed. When two or more behaviour elements, previously defined as existing in the same taxonomy, may occur simultaneously during observation, there must exist a clear working rule for how to deal with the situation. For a taxonomy in which only a few different elements are defined, it is possible to represent both the individual elements and their combinations as separate codes. If the changes between the elements are frequent and sudden, it may be possible to observe the behaviour from film or videotape recordings, one or a few elements at a time, and then to combine the simultaneous occurrences into separate codes at a later date. And if there are many different elements to be observed, it may be necessary to derive a precedence rule for their registration, according to which only the most important one of several simultaneously occurring elements is recorded. But however the problem of simultaneity in the occurrence of the elements of the observed behaviour is tackled, its resolution must not be allowed to result in a decrease in the validity and reliability of the observed data.

One approach which is recommended by Leonard (1984) involves the use of a 'top-down approach' to the analysis of organismic behaviour. This approach is in fact quite similar to the general approach advocated here, and it involves basically that the behaviour to be observed be carefully structured from the top down, beginning with the general behaviour domain and successively deriving the elements to be observed in the necessary detail, which is neither more nor less than equivalent to the derivation of a behavioural taxonomy. Leonard also maintains that the top-down analysis of the organisation of behavioural systems involves the use of a 'complete record', and she advocates the use of various sequential analyses as a part of the top-down approach. While I agree that it is desirable to be able to design the whole of the observational study in detail at the outset, with a complete set of analyses of the data in mind, I shall have to emphasize once more my previous contention that a 'complete record' of the behaviour of an organism may only be obtained within some practical and conceptual limits which also have to be stated at the beginning of the study. As for specifying exhaustively the battery of analyses to be used on the data, I believe

that a certain measure of serendipity will always be needed, even at the analytical stage of an investigation.

The derivation of an a posteriori taxonomy comes as the conclusion of a behaviour observation study, when the analyses of the data are completed and the details of the relations between the elements of the behaviour have been deduced; when redundant elements have been discarded and elements previously not considered for the taxonomy have been included. The a priori taxonomy may be considered as analogous to the research hypothesis posed in an experimental study. But instead of wholly confirming or rejecting this hypothesis, in the behaviour observation study we aim at modifying it in accordance with the freshly acquired evidence, and thus improving our understanding of the behaviour studied. In order to succeed in this endeavour, we must have a well formed idea of how the desired end may be attained; how the taxonomy is to be integrated into the observation system, the observation system into the study as a whole, and the study into the analytic paradigm within which the observation was conceived.

The validity of the results is mainly related to the taxonomy employed, as is also their reliability. The latter depends to a large extent also on the observers and their ability to utilize the taxonomy and other tools at their disposal, while at the same time not influencing significantly the behaviour of the organisms observed.

The registration, transmission, storage, retrieval, and use of the behavioural data is also a sizeable and important part of the observation system, one which must be managed successfully when the observation study is carried out. However, a detailed description of these tools is not considered appropriate at this stage, and the interested reader of this thesis is referred to Appendix A for a description of the computer program packages used for the processing of the observational data gathered in the studies included in the next part of the thesis (q.v.). Furthermore, different methods for registration, analysis, etc. may be found in the published studies included below, as well as in such excellent handbooks on these topics as Hutt & Hutt (1970), Sackett (ed. 1978), Lehner (1979), and Scherer & Ekman (1982); also the large number of papers published by such authorities in this field as Bakeman, Dawkins, Gottman, van Hoof, Sackett, and others. References to many of these works are contained in the reference lists included here.

Turning theory into practice and vice versa.

This section is devoted to a description of the 5 published papers by the author which are included below in their entirety. These papers provide, at least partly, the practical flesh for the theoretical bones of the thesis, and at the same time they illustrate the development of the ideas and the methodology that I have employed in the investigations of different aspects of human behaviour, viz. the reliability and individual behavioural styles of observers of infant behaviour, the work behaviour of telecom operators, and the sleep behaviour of human neonates. The papers are kept in a chronological order to illustrate this

development more clearly. Of the papers, the first and third (Briem & Nyström, 1978; 1984) and the fourth (Briem, 1985) examine partly the methodological and procedural possibilities of behaviour observation, and partly the application to the sets of problems concerned. The second paper (Briem, 1983) gives an outline of the methodological foundation for behaviour observation and describes a preliminary version of a computer-based data-collection system, which is described in a later and more complete version in Appendix A. The fifth paper (Briem, 1986) is mainly concerned with the application of the previously developed theoretical and methodological apparatus to investigate some temporal aspects of infant behaviour.

Paper 1 (Briem & Nyström, 1978) reports the results of what was intended as the first of a series of studies of the development of affective behaviour and communication in infancy. The aim of the study was primarily to clarify some methodological issues related to behaviour observation studies in general, and those of human infants in particular. One of the points of primary interest was the observers' perception of the behaviour under study, and the accuracy with which it was observed. More particularly, the study addresses the problem of the perceptual interaction of the observer with the observed situation, as well as how the sociobiological qualities of the observer shape his or her observational process. As only a small sample of 4 male and 5 female observers was used in the study we did not feel justified in drawing fully general conclusions from the results. Four aspects of the problem outlined above, as it appeared when male and female adults observed a short videorecording of the facial behaviour of a sleeping neonate, were studied: i. Agreement among observers when detecting the onset and offset of bursts of neonatal behaviour; ii. differences in processing ability between observers when confronted with the less informative and less realistic situation of observing only half the infant's face at a time, as compared with observing the whole face; iii. the influence on the observers of having to judge 'pause', i.e. absence of behaviour, instead of the behaviour itself in the infant's face; and iv. the differential sensitivity between men and women to this particular stimulus material.

Through a series of relatively simple statistical tests and decision theoretical analyses it was established that the observers agreed well among themselves as to the presence and absence of the behaviour, as well as with an independent estimate of it. The observers tended to be rather conservative in their estimates of the behaviour, and showed their greatest consistency between the four observation conditions in the tendency to give 'false alarms', (indicating behaviour when none occurred; or indicating pause when there was behaviour present). The female observers also showed a clear relation between the scoring of 'false alarms' and 'hits', (detecting actual signals). Furthermore, the female observers were found to give many very short indications of the presence of behaviour at the beginning and end of actual bursts of behaviour when observing the whole face, a tendency not shown by the male observers.

From these and other results from the analyses of the data we concluded the following: People are, in general quite competent observers, but need initial training in order to attain good consensus as to the identity and size of subjective behaviour units. Women tend to be more sensitive as observers, at least in this particular kind of observation, and all individual observers are better characterized by their errors of commission than any other response measure. Furthermore, in cases where accurate movement detection is required, it gives better results to break down the task into its components, and thereby reduce the information load, although the observed behaviour at the same time becomes less meaningful. However, the accuracy of the observation is greater for actual behaviour than its absence, while at the same time the errors of commission are by far the most numerous in the most realistic of the observation conditions.

Paper 2 (Briem, 1983) describes particularly the methods and apparatus so far developed for the behaviour observation studies. It includes short historical and theoretical reviews, as well as a description of the data-collection terminal, Micronic 445, used for the studies described in Papers 3-5. The terminal can be used in three different registration modes which are usual in behaviour observation studies, viz. 'occurrence', 'timing', and 'event-recorder' modes. The paper also contains a description of a registration and analysis system for the latter two of the recording modes, with the help of which the data collected may be processed and analyzed.

The use of electronic data-gathering devices from which observational data may be transferred directly to a computer memory constitutes an appreciable gain in time and effort. Subsequent computer processing of the data, including summary statistics and sequential analyses, provides the investigator with an even greater advantage. But any realistic use of these facilities is made possible only through the application of an appropriate conceptual system which guides the observation study from the initial observation to the final conclusion. The constructs introduced here as serving these ends are the 'a priori' and 'a posteriori' taxonomies which allow the investigator to assign a relevant structure to the behaviour under study. However, as a primarily methodological paper, it is particularly concerned with what happens in between the construction of the a priori taxonomy and the derivation of the a posteriori taxonomy, viz. the observation methodology itself.

In **Paper 3** (Briem & Nyström, 1984) an extension of the use of behaviour observation methodology to the study of the work behaviour of telecom operators is reported. The Paper begins with an examination of how various methods have previously been employed for examining job content and behaviour at the place of work. It then carries on with a comparison of these methods with those derived from ethology for the study of various aspects of human behaviour. There appear to be many common factors in both these approaches. Thus, e.g. 'task analysis' makes use of hierarchical models of the work content, and flow diagrams tend to be extensively employed in the traditional description of work sequences. Consequently, it seemed appropriate to apply observation of the

telecom operators' behaviour while at work, comparing here the behaviour in two analogous work situations, and at the same time assessing the power of this method for estimating such factors as relative work efficiency.

These factors were examined in a small group of telecom operators at their normal place of work in either computer aided or conventional information service. We started by establishing an a priori taxonomic structure by which the telecom work situation could be exhaustively and unambiguously described, and with its help we were able to estimate the relative size of the various work behaviour components. We discovered that the telecom task itself appears to impose a fairly stable structure on the activities of the operators. At the same time the behavioural profiles of each operator were quite unique. The general task structure seemed, in its turn, to result in considerable 'ineffectiveness' in work performance, where on the average only about 60% of the time studied was spent in actual information search and exchange, while about 40% was spent in other activities. However, the results did not provide any direct indication as to how and to what extent the effectiveness might be improved or if such an intervention was desirable or even possible. On the other hand, the efficiency of the computer assisted telecom work was, at least in this sample, about twice as high as that in traditional telecom work.

From this study we concluded that behaviour observation is eminently suited to studying various aspects of work behaviour and social interaction at the place of work, and we propose several alternatives according to which this methodology may be applied to work study in general.

Paper 4 (Briem, 1985) contains a more extensive analysis of the telecom operators' work behaviour first reported by Briem and Nyström (1984). Here, the emphasis is placed on examining the sequential and temporal relations between the component categories of the a priori taxonomy previously applied in the behaviour observation and registration. The paper should also be seen as an attempt at developing a better behaviour observational methodology for investigating work behaviour and work related behaviour. It begins with a short review of the various uses of observation methods for studying behaviour, and a comparison of traditional work study methods with those of behaviour observation, together with an assessment of the relative merits of each. Then, after redefining the behavioural taxonomy of the telecom work behaviour previously presented, the reliability and validity associated with its use were examined and potential sources of disagreement in the registration were isolated. Subsequently, the data from the observation were subjected to statistical analyses, in particular lag sequential analyses, in order to examine the internal relations in the sequences of observed behaviour, and the results were summarized in probability profiles and state diagrams.

A large part of the paper is concerned with the definitions and clarification of concepts and relations employed in sequential analyses of behaviour in general. These definitions were considered necessary because of the relative 'fuzzyness' of many

of the concepts, relations, and other theoretical tools employed in this type of analysis.

The results from the lag sequential analyses of the telecom work behaviour showed that, given the particular a priori behavioural structure used here, many of the sequential characteristics discovered were consistent with a more common sense analysis of the telecom work. However, various novel features of the work and work-social behaviour gradually emerged as the analyses were carried through. Thus, each individual operator could be shown to have a characteristic behaviour profile, at least within the somewhat limited situations studied. At the same time, the task itself moulds these profiles, and distinct features may be discerned for each of the two types of telecom work done.

It was concluded that behaviour observation is in many ways better than the more traditional work study methods, especially as it allows a more comprehensive and rigorous analysis of the data. The introduction of behaviour observation methods into applied research also gives the investigator the opportunity to study simultaneously such disparate aspects of the work situation as individual efficiency and aptitude for the job, the effectiveness of different work routines, as well as social interaction and even job satisfaction.

Paper 5 (Briem, 1986) concludes in a way the behavioural study of child development first embarked upon by Briem and Nyström (1978). It utilizes the same kind of behavioural material as previously, but now both the aim of the study and the types of analysis of the data are different. The paper begins with a review of the relevant literature, and at the same time, neonatal facial behaviour in active sleep is placed into its rightful context of activity rhythms and behavioural states. These behavioural changes are also related to results from EEG studies and to hypotheses concerning the ontogeny of brain function in human beings, and in the light of this evidence it is proposed that there is a cyclic relation between neural activation, observed variation in the amount of sleep behaviour, and the behavioural states seen to exist in infants.

To test these hypotheses a battery of behaviour observation and analytical techniques (cf. Briem, 1983 and 1985; and Appendix A) were brought to bear. With the help of these methods, as well as some fresh ones developed in connection with this study (cf. Appendix A), the behaviour observation data were tested, transformed and analyzed in various ways. It then transpired that the amount of facial behaviour produced by the neonates in the state of active sleep varied temporally, with distinct bursts of behaviour occurring in what first appeared to be an irregular rhythm. But by subjecting the data to a series of sequential and spectral analyses and function-model fitting, it was subsequently shown that the variation in bursts of active sleep behaviour could be described as a compound rhythm, and the component cycle periods could be predicted from a geometrical function of cycle length against its order in the progression. Other, known behavioural activation rhythms could also be extrapolated from this function.

These results were related to models of brain function and neural activation, and to the available knowledge about the relation between behavioural activation and brain development. The general conclusion drawn from these results was that, while not all the biological consequences of diurnal and other rhythmic variations in the behavioural activity of organisms are known at the present time, some of these cyclic changes are known to have definite survival functions, and all are related to and to some extent governed by innate neural principles. Furthermore, it is possible that both the short-term changes observed in this study and other, less frequent variations in neural activation are in any organism modulated by a single, common, super-ordinate, physiological mechanism, and that the charting of the function of this mechanism may resolve many of the puzzles connected to the specificities of our day-to-day functioning.

Conclusion.

The primary concern of this thesis has been to present behaviour observation as a methodology for studying differing aspects of the behaviour of organisms, to examine some fundamental issues related to the **theoretical basis** on which behaviour observation rests, as well as to illustrate how the methods may be used to obtain answers to a wide range of questions about behaviour. The thread that most conspicuously runs through this work is thus what I consider to be the proper use of such concepts and techniques as are available to the investigator in a behaviour observation. This practice may not always be entirely straightforward, and looking at the body of empirical evidence which has accumulated in this area during the last half century, it becomes clear that some students of behaviour have at times not been aware of the consequences of the uses to which they have put the conceptual apparatus at their disposal.

It is usually easier to see the implications of most arguments and hypotheses in retrospect when they have been subjected to the public scrutiny of others. However, my aim in this thesis has not been to criticize but to examine and discuss, and where possible to uncover more fruitful alternatives to those which have caused confusion instead of clarification. One of the points that I have attempted to make is that the 'meaning' of a behavioural element or sequence is never obvious a priori, but instead always a more or less educated conjecture. Of course, the more we know about the behaviour under observation, the organism producing it, the circumstances of the behavioural production etc., the more reliable our perception of it will become, and the better we are able to describe, predict, and explain it. But however good our knowledge of the observed behaviour is, the fact always remains that it must normally be attained through the application of a perceptual apparatus, and is thus subject to all the errors and inconsistencies that this apparatus imposes.

As a consequence of these limitations, the best way of getting to grips with the problems encountered in the study of organismic behaviour is to learn more about how we perceive and represent this behaviour cognitively. As a first step I proposed the use

of two related structures for this purpose, the 'imposed' and 'underlying' structures. The former of these is the structure which we assume the immediately observed behaviour to have, and which includes assumptions about its meaning. But as we are usually aware that there are other, alternative interpretations of the meaning of the behaviour, we also assume other, less directly available structures which are taken to carry the ultimate meaning of the structure which was the cause of our experience. Thus, we infer an underlying structure from the one originally imposed on the behaviour observed.

The inferred, ultimate cause of the imposed structure may not just be a single structure, and we may instead infer a chain of causes leading up to the structure which we perceive the behaviour to have. Thus, the underlying cause may be analyzed into a 'deep' and a 'surface' structure of behaviour, where the former results in the latter through the action of some further causal mechanisms. These postulated, underlying structures may very well be necessary to clarify some of the reason for the perceived shape of the structure of the behaviour observed, but in the end, they must be seen as only a part of the reason, i.e. that part which belongs with the behaviour-producing organism. The rest must reside with us, the perceivers.

The perception of a structure in behaviour is by no means a passive process, and we make use of a variety of conceptual structures in order to accomplish it. Some of these may be seen as a priori forms and tendencies which shape the direction in which the perception is taken, while others are methods and tools explicitly made up to enable us to gain a clear idea of what the recondite reality is with which we are faced. In my analysis of these tools, I have been particularly concerned with classification, systematization, and the logical relations governing the use of these systems and models in behaviour observation. In this connection I have attempted to show how models may be used to clarify differences of points of view, how solutions may be found through the use of simple models, and also that the manipulation of these models may suggest further theoretical developments.

Although models are often useful for clarification and for stimulating to new ideas, they may at the same time steer the investigator into a cul-de-sac by suggesting solutions which although superficially plausible are also logically flawed or in conflict with other, more reliable data. Therefore both the internal logic of models of behaviour and their concordance with the external facts must be carefully checked out at all stages of a behaviour observation, before they are allowed to direct the on-going research further. But the flaws in the model may not be apparent at once, and the relevant observational and experimental evidence may not become available until at a later date. In these cases the critical examination of the model will be deferred, and it may indeed be necessary to let the model guide research for a while before the results of this particular one and other investigations are sufficiently contradictory to the model to have it modified or replace with another, more suitable model. However, although theoretically salubrious experience may be gained from the testing of a faulty model, such a practice

does seem somewhat unnecessary, especially as it should have been avoided in the first place.

In the empirical work described in the previous section we were faced with the choice of either commencing the studies with explicit models of the behaviour observed, models which would then be tested and finally confirmed or rejected; or alternatively to start by advancing tentative *a priori* structures together with fairly loose assumptions about them, and then to modify these structures as we went along. We chose the latter alternative for the first studies in both the areas investigated (cf. above: Briem & Nyström, 1978 and 1984). In the former of these, the main interest was in finding out how the observers, who were naive with respect to observing the particular material used in the study (videofilm of a sleeping neonate), would spontaneously structure the behaviour in the observed sequence when their only requirement was to indicate the presence and absence of behaviour in the neonate's face. The only *a priori* structure used in this study was the 'signal' behaviour sequence which was adjusted and compiled from our own previous, repeated observations of the material. This signal sequence represented our best approximation to the presence and absence of behaviour, and it was subsequently compared to the observers' registrations of behavioural occurrence. On the other hand, the *a posteriori* structures which emerged from the analyses of the observational data were somewhat more complex: They were combinations of the records of all the observers, and represented the probability of obtaining a response to the signal under differing stimulus conditions, by observers of either sex, and when the signal consisted of different facial Gestalten. Each of these factors affected the response distribution in a different way. Although there exists no published follow-up of this study, where the findings are utilized further, it is clear that an *a posteriori* signal structure in a study of this kind contains far more information than does the *a priori* structure used here, as in it all the factors found to affect the shape of the structure have to be taken into account.

The latter study employs a different type of *a priori* structure, viz. the type which has been discussed previously in this thesis at a considerable length, an *a priori* taxonomy for use by the observers in registering the telecom work-place behaviour observed. This *a priori* structure does not contain any assumptions as to when the operators were expected to respond, as we were, of course, unable to establish a signal sequence beforehand. Instead, it contained a logical break-down of the classes of telecom operator behaviour, and it did not encompass any preconceptions about the proportions taken up in the total behaviour periods by each of these categories. The use of the taxonomy in the registering process was utterly straightforward, except for the fact that some of the information relevant to the change-overs between certain categories was not available during the observation, which led to some decrease in reliability.

In the follow-up analyses of the data from this study (Briem, 1985), a succession of sequential analyses was used to obtain information about the relations between the behaviour units. What these analyses eventually revealed was that, although the taxonomy was applicable to the group of subjects observed, the beha-

viour categories were unequally represented in the observed sequences for the individual operators. Also, the work content in different work routines was observed to influence the sequential contents considerably. These findings did not occasion an immediate a posteriori change in the taxonomy, but indicated how it might be modified and extended in subsequent studies. The follow-up analyses also demonstrated the necessity of introducing new ways of representing the results during the course of a study, as well as the fact that various different a posteriori structures must be available to the investigator.

A similar conclusion may, among other things, be drawn from the second neonate study (Briem, 1986). In this study, as in the first neonate study, the a priori taxonomy was basically a binary one, i.e. the observers recorded only the presence of behaviour, and a default, no-behaviour (NULL), category was automatically recorded in-between. However, a more complex taxonomy was intended from the start, one which included variations in the amount of behaviour during the course of the observed sequences. This plan resulted from the conclusions from the first neonate study, where it was shown that the probability of facial behaviour being recorded is greater when one observes only a part of the face at a time and subsequently combines the resulting sequences. Similarly, the error arising from variations in observational accuracy may be minimized by combining several, recorded sequences for the same behaviour. Both these findings were utilized in the design, and the result was a derived taxonomy which described the variations in the amount of behaviour occurring in the infants' faces, as observed from three facial regions. For this taxonomy it was also postulated that changes in observed behaviour from one element to another would only be up and down, but not sideways in the hierarchy, i.e. it would be a 'true' hierarchy. This assumption was tested in both sequential and non-sequential analyses of the data, and found to hold true, which clearly implied that the neonates' facial behaviour occurred in well defined and discrete bursts. By further subjecting the data to time series analyses, it could be demonstrated that the lengths of the intervals between bursts could be ordered in a geometrical series. Thus, by the successive application of a number of simple models many interesting properties inherent in these particular sequences of behavioural data could be discovered.

Scientific methodology tends often to be taken for granted by those who employ it, but as long as the methods used are the appropriate ones and they are correctly applied this does not matter. But even the most accomplished and inveterate investigators have been known to err in their judgement in these matters, sometimes with unfortunate consequences. It may to some seem facile to reiterate that errors of this kind ought not to be committed. But as they are and will continue to be made, it does indeed seem useful to examine closely the causal sequence which leads to them, and try to find some remedies.

In this thesis I have discussed at length various of the conceptual tools available to those who study the behaviour of organisms. I have stressed the importance of the use of scientific logic in the analysis of the conceptual structures used for

describing behaviour from the start to the finish of an observational study. What I consider to be especially relevant here is a close attention to the definitions of the behavioural units, the relations that must be postulated during the definitions of the individual ones of these units, as well as the relations that have to be postulated when we wish to refer to more than one of the units simultaneously. A few investigators before me have felt the need to clarify some of these concepts and relations. But in spite of this I keep coming across misconceptions resulting from the erroneous definitions and application of these relations in behaviour observational research. Consequently, I too have felt the need to re-examine these relations and the concepts attendant to their use in this field of enquiry. If some readers of my thesis have felt that I have pointed out similar things more than once or too often, let me remind them that certain things **need** to be reiterated before their impact is felt.

Notes.

(1) In a previous work (Briem, 1975) I have discussed in detail similar inferential mechanisms for perception in general and the perception of size and distance in particular. These inferential mechanisms are equally applicable in the present context to the perception of behavioural structure. In general, the theoretical position which I represent here owes a lot to ideas such as those of Spinoza (cf. Hampshire, 1951) in that I maintain that a person's percept of any object results from the state of his perceptual system at the time of perception, as well as the state of the perceived object. Thus, the perceived object is not a 'picture' of the external object, but a unique modification of the person's internally coherent perceptual system. The modification occurs continuously and is in action at the 'moment' of perception. This theoretical position may, for example, be contrasted with that of J.J. Gibson (1966), who proposes that all the information necessary for perception of the world is contained in the environmental stimulation of the organism, and that no reference to inferential processes is necessary in this context. Gibson's view is also relatively easily refuted by reference to empirical evidence.

(2) It is not my intention here to revive this controversy of 'innate vs. learned', so many years dormant. Neither is this thesis intended as a discussion in any detail of the interaction between phylogenetic and individually acquired behaviour patterns, even though these aspects of the shaping of an organism's behaviour are of considerable importance, not least with regard to both the generalizability of results from behaviour observation studies and in the further discussion of behavioural causation. On the other hand, it is essential to have a sound understanding of these principles generally when one designs behaviour observational studies, and in particular in the construction of behavioural taxonomies.

(3) I want to stress that these models represent my own interpretation of the views expressed by Lorenz and Tinbergen, and as such they do not necessarily represent the the actual views of those two theorists.

(4) This is an integral part of what I refer to in this thesis as the 'a priori taxonomy construction' for the behaviour under study. There are, of course, other ways of describing behaviour than the morphological and the functional. Other modes of particular relevance here would be those in terms of causes and purpose. However, they have been treated extensively by, for example, Peters (1958).

(5) These two senses of the concept of 'function' as a behavioural 'consequence' is what Hinde (1975) refers to as its 'strong' and 'weak' senses. 'Function' in Hinde's terminology refers thus to any beneficial consequence of behaviour (the weak sense), or to the critical consequences through which biological selection acts to maintain the behavioural character in its existing form (the strong sense).

(6) Nissen (1971) shows that statements about 'function' in the biological sense are not equivalent to (simple) statements about

'effect'. Furthermore, he provides "substantial evidence for the position that all functional statements (a) are causal statements (and not statements about probabilities or necessary conditions), and (b) have implicit reference to goals" (p. 256). While I believe that Nissen is in substance correct in his proposals, I also think that his statements need further qualifying. Therefore, I want to propose the following:

i. The functional relation, 'the function of x is y', or (FUNCTION(x,y)), is concerned with the use of something or the attainment of a goal, rather than with the actual end state or goal itself.

ii. In biology this relation is used to define or confer meaning of a certain kind onto a label referring to an organ or behavioural unit, i.e. to explain its existence in terms of a beneficial consequence or survival.

iii. It is therefore, a different type of relation than the ones existing between events or behavioural elements; i.e. it is neither a static or a dynamic relation.

iv. The functional relation would be better described as an effect relation than a causal relation.

A corresponding 'structural' relation may also be postulated. It would define items falling into the morphological category, and be expressed as, for example, (STRUCTURE(A,X1,...)), where the morphological properties, X, are enumerated for element A.

(7) I shall not try to define 'reality' here, partly because I do not believe that it is necessary in this context, and partly because I believe that any general definition of 'reality' will be a fairly subjective one. However, my definition of the surface structure of behaviour may be seen as a very limited definition of one aspect of what I refer to as 'reality'.

(8) This account of validity was adapted from Hollenbeck et al. (1975), who in turn had adapted it from the APA's recommendations with regard to the construction of psychometric tests.

(9) The dynamic relations between units may be qualified in different ways. Thus, if one wants to avoid the theoretical implications that using such a term as 'facilitatory' or 'inhibitory' entails,, one may instead use the more neutral qualifications 'positive' and 'negative'. This also carries the added advantage of being easily generalizable to other experimental results. Another qualification is 'immediate' and 'delayed' for the influence of A on B. (Cf. Briem, 1985, for a discussion and examples of the uses of these qualifications.)

(10) I use the term 'category' here to denote a superordinate group of behaviour units, although generally, 'category' may be considered to be synonymous with 'unit', 'element', and 'item' of behaviour. Thus, for instance, stating that a 'unit of behaviour' has been observed, is equivalent to stating that the observed event has been classified as being an instance of behaviour corresponding to the description of the category that the unit was defined as belonging in.

(11) There are certain dangers associated with combining functional and morphological units in the same taxonomy. However, these dangers may in practice be evaded by careful attendance to the definitions of and relations between the units.

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The Detection of Infants' Facial Movements

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A b s t r a c t . - Nine observers, 5 female, and 4 male, watched a 345 secs. long videorecorded sequence, which showed the facial behaviour of a one week-old infant during active sleep (REM). Four instruction conditions were employed: The observers recorded movements in the whole face (W), the upper half of the face (U), and the lower half of the face (L), and absence of movements (P) in the whole face. Observers showed high consensus and their pooled response distribution was significantly correlated with the infant's behaviour ($r_{pb}=0.67$). The response distribution for P was almost a perfect inversion of that for W ($r=-0.86$). Activity was relatively independent between the two halves of the face ($r=0.19$) but the combined response curve (U+L) was very similar to the one obtained for W ($r=0.85$). Disagreement among observers mainly occurred at the beginning and end of bursts of activity. Very brief registrations were much more abundant among female than male observers ($p<0.01$). This together with other findings from signal detection analyses indicates that female observers show, generally speaking, greater sensitivity to the task of detecting facial movements in infants.

I n t r o d u c t i o n

It seems that we normally react to and interpret the movements of another person in an automatic and often unconscious way. Moreover, these movements are experienced as acts and actions, and not just as random behavioural occurrences. Thus, we may under some conditions interpret certain contractions of the face ("crying") as a show of grief, and under others as a show of joy. But, although the meaning of many movements can appear ambiguous, there is less doubt attached to their interpretation when they are set in their natural context of the behavioural stream than when they are considered in isolation (Schefflen, 1965).

Even if the meaning of the behaviour is not as socially obvious generally as in the case of crying, it is at least possible for one person to segment the behavioural stream of another into different units or groups of movements-such as the ones which are used for classification in various observational studies (Sackett, 1978). When we ask ourselves why this is so,

two main possibilities offer themselves. The first of these is that the meaning attributed to certain movements is fairly constant for all observers (cf. Ekman, 1977), thus providing a framework into which to fit other behavioural elements; the second possibility is that different observers divide the stream of behaviour into similar sections or sequences, dependent on some subtle cues inherent in the situation, irrespective of the attributed meaning.

It is difficult to decide whether one of these two alternatives offers a truer picture of the behaviour segmentation than the other or if both are tenable, but we know, at least, from a series of studies by D. Newton and his associates (e.g. Newton, Enquist & Bois, 1977) that the latter alternative is highly probable. These studies, where the observers' task was to segment concrete and goal-directed ongoing behaviour sequences into their component actions, indicate a high degree of consensus among observers in judging the "break-points" between "action units". As yet we do not know if this is also true of the judgement of non-verbal communication behaviour, in particular facial behaviour, although this seems likely.

In an earlier study of the facial movements of neonates by one of the authors (Nyström, 1974), two independent observers showed a fairly high agreement in their division of sequences of behaviour into different categories of behavioural items. However, it happened in some cases that one of the observers would note down the occurrence of a behavioural item when the other did not consider that any change had taken place in the infant's expression. We suspect that these differences between observers can in many cases be due to their different perceptual thresholds for the detection of facial movements. In other cases, however, the reason may be that different observers at-

tend primarily to certain behavioural items and to a lesser extent to others (cf. Hollenbeck, 1978).

Our aim in the present experiment is to take the study of behaviour segmentation to an even more fundamental level than has been done previously, one where the observer's task is simply to divide the stream of behaviour into the presence or absence of movement. The behaviour observed is that which occurs in the face of a sleeping neonate. By simplifying the task in this way we hope to gain some valuable information concerning how different observers go about performing this basic task and what factors influence their performance. Furthermore, in order to make this experimentally viable we have put forward a number of more or less specific questions to which we hope to be able to provide some answers.

First of all we pose the question of whether different observers of the same facial behaviour will be in agreement as to the presence or absence of this behaviour. Is it possible for the observers of a complex mimic stimulus to localise precisely the points in time when facial movements start and stop? Or will the detection of facial movements always vary between observers, e.g. because of differences in their thresholds of detection? If there exist individual differences in the capacity for detecting facial movements, how can these differences best be conceptualized?

Another question which follows from the first one concerns what kind of influence the observer's sex is going to have on the observations he/she makes. One could, for example, suppose, that women, because of their special biological status, have a certain predisposition for detecting changes in emotional states in the neonate. We would, therefore, expect female observers to be more accurate in their observations of infant facial move-

ments than male observers. The same result might be expected if one supposes that women, because of their traditional social status, learn to take more interest in newborn babies than men do.

The third problem concerns the amount of information that the observer has to deal with when he/she has to detect movements in several different parts of the face. Allowing that there are more possible movements to keep track of in the whole face than there are in any part of the face, then the observers' task should be made somewhat easier by limiting the relevant signal-area to only half of the face. The results from two separate observation sessions of this kind, in which the signal-areas were the upper and lower halves of the face, respectively, should then together give a more complete picture of what is going on in the whole face.

A further problem concerns the relative contributions of different parts of the face to the observer's judgement of quantitative variations in facial movements. Are movements in some parts of the face easier to detect because of their relatively greater amplitudes than movements in other parts? A similar question relates to the variation in the kind of observations that result from different instruction sets as to what to attend to in the behaviour sequence observed. Is it easier to register the occurrence of behaviour than the non-occurrence of behaviour?

M e t h o d

Nine students from a course in ethology, five female and four male, all of them in their twenties, served as observers. They had had previous experience of naturalistic study and were highly motivated to do the task. All of them had normal eyesight, two of them with the help of glasses. The observers took part in the experiment one at a time.

The study began with a four minutes' warming-up period during which the observer watched a film which demonstrated the facial behaviour of a sleeping newborn baby (Super 8 colour film). The experimenter pointed out and commented on the facial behaviour during the showing of the film. Directly afterwards the observer was taken to the experimental room where he/she watched a one minute long videorecording (black/white) of similar behaviour of another neonate. The child's face was shown in close-up on a 23" screen at a distance of approx. three meters.

The main experiment consisted of the observer watching a 345 secs' long sequence of the same child's facial behaviour during active sleep (REM). The observer watched the sequence four times, each time under a different set of instructions as to how to respond and with a short rest-period (about five minutes) between each showing. The response conditions consisted of the observer holding down a button which activated the pen of an event-recorder (speed of moving paper strip was two mm per sec.):

- a. as long as any kind of behaviour could be observed in the child's face (condition Whole Face = W),
- b. as long as no behaviour could be observed in the child's face (condition Pause = P),
- c. as long as any behaviour was seen to occur in the upper half of the face (condition Upper Face = U), and
- d. as long as any behaviour could be observed in the lower half of the face (condition Lower Face = L).

The difference between conditions U and L lies in that in U the observers pressed the button when there was behaviour above a line which he/she imagined to be drawn across the child's face, and in L he/she pressed the button when there was behaviour below this line. The line was imagined by the observer (in accordance with instructions) to transverse the child's face across

the middle of the bridge of the nose across the cheeks, such that movements in the eye-region constituted a signal in condition U, while movements around the nostrils and the cheeks were a signal in condition L. Only movements in the face itself were taken to be signals, and movements of the whole head as well as other bodily movements were disregarded.

The four experimental conditions were presented in a balanced order, such that every other block of two observers were given instructions W and P first and U and L second, while the following block of two observers watched first under instruction U and L and then under W and P. The order of presentation of conditions within the blocks was systematically varied.

The 345 seconds' long stimulus sequence contained the first part of the neonate's active sleep (REM) period. In all, 66 facial behaviour items (cf. Nyström, 1974) could be observed during this sequence. The position of these items in the sequence are shown together with the corresponding symbols under the temporal axis of condition W in Fig. 1.

The temporal distribution of the neonate's behaviour was determined through careful analysis of the behaviour sequence by the two authors. This distribution was taken to represent "the actual behaviour" which takes place during the sequence, and will hereafter be referred to as "the signal distribution". The activity thus defined is referred to as "the signal" and a single, unbroken series of behavioural events is referred to as "a signal". The signal distribution is shown directly under the temporal axis of condition W in Fig. 1. A signal occurs 26 times in all during the sequence, with an average duration of 7.2 secs.

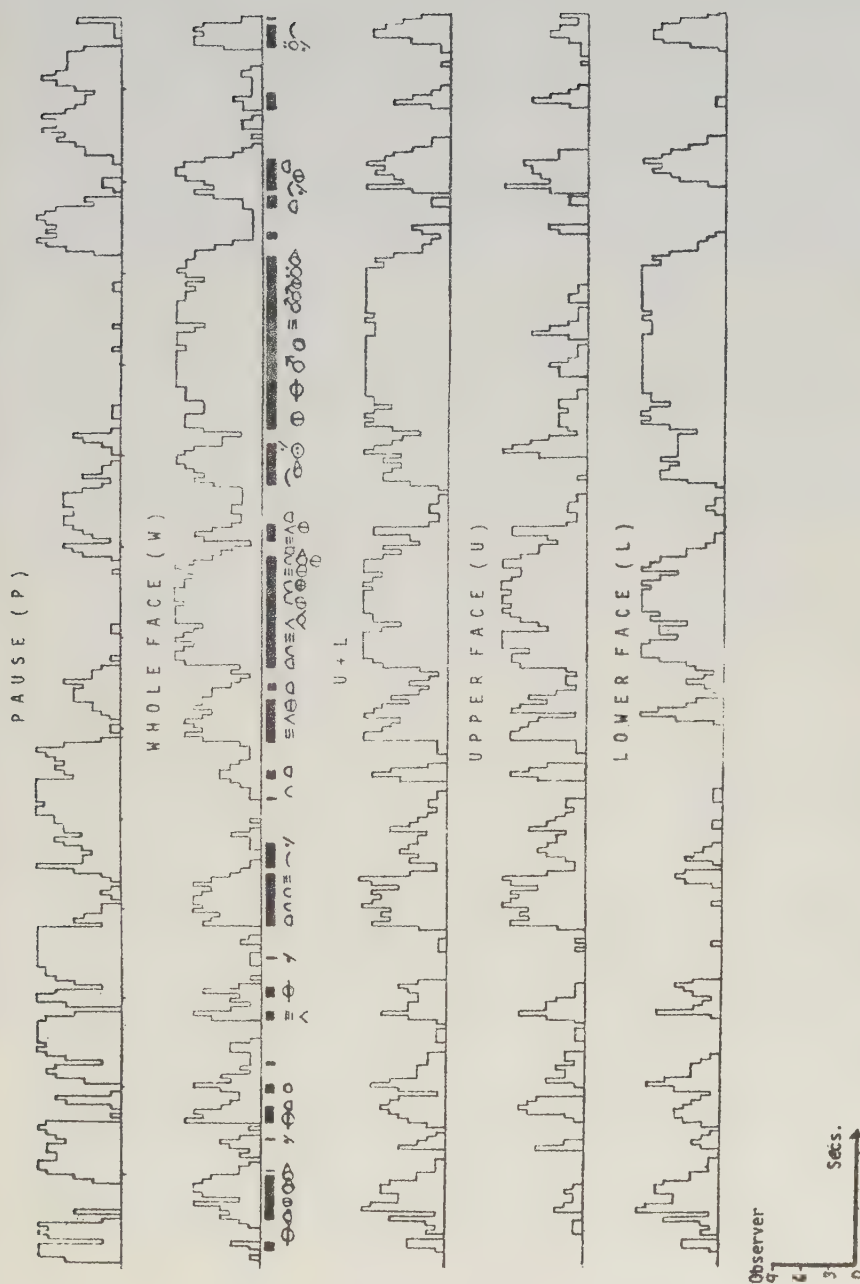


Fig. 1. The pooled distributions of the nine observers' registrations of infant facial behaviour under four observation conditions. The fifth response curve is the overlap of the ones for conditions U and L. Presence of activity (bars) and specific behaviours (cf. symbols in Table 3) are depicted for the condition W.

Results

Activity was on the average judged to occur in 46 percent of the observation time for the nine observers in the whole face condition (W). Since the average registration of pause (P) was only 42 percent, there was a "zone of uncertainty" during which neither presence nor absence of behaviour was registered. This zone amounts to more than ten percent of the total time and seems to be a reliable feature since all subjects reveal this trend (Table 1).

Table 1. The percentage of time registered under four observation conditions. Values in brackets give the mean duration of registrations in secs.

Condition: Whole face	Pause	Upper face	Lower face
Subject (W)	(P)	(U)	(L)
1	61 (7.3)	32 (6.0)	36 (4.2)
2	54 (7.4)	38 (4.0)	36 (4.7)
3	64 (11.1)	33 (8.9)	40 (5.9)
4	39 (4.7)	35 (7.2)	22 (3.5)
1	34 (4.6)	56 (8.7)	10 (1.7)
2	47 (5.7)	32 (4.1)	44 (5.8)
3	32 (2.8)	56 (6.3)	14 (1.6)
4	40 (4.0)	43 (5.1)	18 (3.2)
5	43 (7.1)	54 (7.5)	34 (4.1)
Mean	46 (6.1)	42 (6.4)	28 (3.9)
			37 (6.1)

A good idea of the observers' response to the signal will be gained by referring to Fig. 1. This gives a graphic representation of the pooled responses to the signal, obtained by constructing a frequency distribution of the responses made under the four conditions (W,P,U and L) by the nine observers. At the top is the response curve from condition P. The curve below, which depicts the judged presence of behaviour, condition W, is, as expected, a nice inversion of the curve above. The negative correlation between these two response curves is

highly significant. The correlations given in Table 2 were calculated from the response frequencies obtained by dividing the material at 1.25 secs. intervals during 345 secs. long responding sessions (N=276, all coefficients give $p < 0.001$, one-tailed)

The signal distribution is shown as a series of bars underneath distribution W in Fig. 1. Fortyfour percent of this distribution represents "signal" and 56 percent represents "no-signal". It may be seen that the achievement of the group of observers agrees very well with the signal distribution. The point biserial correlation between the two has a coefficient of $r_{pb} = 0.67$, with an associated $p < 0.001$. (For this correlation the response material was divided into 1.25 secs. sections, but only 50 randomly selected intervals were used in the calculation because of the pronounced interdependence between adjacent intervals).

Table 2. Correlation coefficients between four different observation conditions. The letters W,P,U and L refer to instructions "Whole face", "Pause", "Upper face" and "Lower face", respectively.

Condition	P	U	L	U+L
W	-.86	.45	.78	.85
P		-.44	-.78	-.83
U			.19	.59
L				.81

Under the part-face observation conditions, U and L, activity was on the average judged to be less frequent than in condition W (cf. below). The two curves at the bottom of Fig. 1 give the observers' responses under these two conditions. Activity in the two halves coincides to some extent ($r = 0.19$), but it appears to be more abundant in the lower half of the face during the later minutes of the session.

The curve in the middle of Fig. 1 is constructed by summing the

response from the two curves just mentioned (U and L). This summing was done by taking the maximum frequency at each point in both distributions and including in the new distribution the one frequency which was the higher. The resulting "overlap" distribution is very similar to the one obtained by observation of the whole face ($r = 0.85$). The correlation coefficients between all five response curves are given in Table 2.

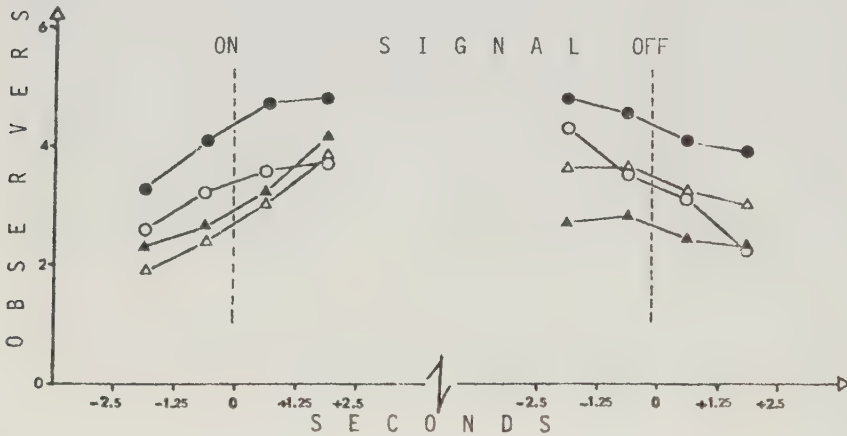


Fig. 2. Mean number of observers responding within the five-secs. interval surrounding the beginning (on) and end (off) of all signals. The values for conditions W,P,U and L are plotted separately. (W=filled circles, P=open circles, U=filled triangles, L=open triangles).

Another aspect of the response distributions, as shown in Fig. 1, concerns the degree of synchronisation between different observers and is shown in the rate of the rise and fall of the response curve. We analysed this by measuring the height of the function during the two 1.25 secs. periods which immediately preceded and the two which followed the beginning of the signals, and similarly for the four periods around the end of the signals. By finding the average for each of these four periods at the beginnings and the average for each of the

four periods at the ends of all signals we obtained the mean rise and fall rates of the responses, irrespective of the response length. These means are shown in Fig. 2.

The mean percentages of the time that observers responded under the four instruction sets, W,P,U and L, were 46,42,28 and 37 percent, respectively (Table 1). A Friedman two-way ANOVA shows these values to be significantly different ($\chi^2_r = 9.2$; $p < 0.01$). A break-down analysis by Wilcoxon matched-pairs test shows a statistically significant difference between the pairs, W/U, W/L and U/L ($p < 0.01$, 0.02 and 0.01, respectively). However, it may also be seen from the data that the lengths of time that the observers responded in conditions W,U and L are positively correlated, and also that the lengths of time of responding in condition P is negatively correlated to the others. Thus, an observer who responds a lot in W,U and L tends to be relatively passive in his/her responding in condition P and vice versa ($r = -.75$, $-.76$ and $-.64$ for P/W, P/U and P/L, respectively, all of which are significant at the 5 percent level).

One might surmise that the difference in average length of time of responding under conditions U and L was due to differential observation or observability of movement items occurring in the two halves of the face. Thirty-three of the 66 circumscribed items that occurred during the 345 secs. signal detection (cf. p. 5) were upper face items and the same amount belonged to the lower face. These were then further divided into items having small physical magnitude and items having great physical magnitude. The resulting list is given in Table 3. Apparently, there is no difference in the number of included and excluded items in observation of the upper and lower face. However, and not unexpectendly, for both halves of the face there was a

significant difference in the number of items of great and small magnitude that were omitted (Table 3: Fisher's exact probability test gives $p < 0.05$ and $p < 0.01$ for the lower and upper face, respectively).

Table 3. The number of behaviours of varying magnitude and site which were included or excluded in the registration of of activity under condition "whole face" (W).

Lower face		Incl.	Excl.	Upper face		Incl.	Excl.
<u>Great magnitude</u>				<u>Great magnitude</u>			
○ General mouth movem.	2	0		≡ Horizontal wrinkles	7	0	
○ Opening of mouth	2	0		○ Elevated eyebrow	6	1	
○ Chewing or sucking	7	1		□ Grimaze	1	0	
○ Protrusion of lips	5	0					
○ Protrusion of tongue	3	0					
total	19	1		total	14	1	
<u>Small magnitude</u>				<u>Small magnitude</u>			
⊖ Compression of lips	1	0		∕ Eye movement	2	4	
⌒ Movem. upper lip	2	2		○ Eyelids raised	4	4	
⊖ Movem. corner of mouth	3	1		△ Contracted eyebrow	3	1	
○ Corner of mouth down	1	0					
⊕ Lips back and up	1	0					
○ Movem. of nostrils	0	1					
○ Movem. of ear	0	1					
total	8	5		total	9	9	
T o t a l	27	6		T o t a l	23	10	

It may be seen (Table 1, values in brackets) that different observers show highly individual response styles: some respond sparingly while others are more generous with their responses. Similarly, it may be seen from the individual records that some individuals tend to respond in many short bursts while others respond in a small number of longer registrations. If we consider the task as one of vigilance and employ the terminology of signal detection theory, the observers can be said to make "hits" a "misses" as well as "false alarms" and "correct rejections". The observers' per-

formance could then be expressed as the ratio of the percentage of hits to that of false alarms. This ratio is given for all observers in Fig. 3. In general, persons who tend to respond a lot have higher percentages in both the hit and false alarm categories. Subjects showing a high percentage of hits without making many false alarm responses can be said to be accurate observers.

The usual type of function fitted to the data in signal-detection studies is one where both axes (x = false alarm, y = hit) are normalized, and this yields what is known as an ROC plot. As regards the data from the present experiment, it was found that the best curve fits were obtained by log-transforming the x -axis of the hit/false alarm plot and leaving the y -axis untransformed. The functions thus obtained for the whole group of observers had the formulae, $y=42+11 \log_e x$, $y=42+12 \log_e x$, $y=18+17 \log_e x$, $y=50+9 \log_e x$, with $r^2=0.34$, 0.85 , 0.68 and 0.30 , respectively, for conditions W, P, U and L. However, further analyses of the data revealed that these must be considered to derive from two different sets, viz. those obtained from male and female observers, and that curves fitted to these two sets of data separately, differed radically both with regard to the slope of the function and the reliability of the fit for all observation conditions. These data together with the fitted regression lines and the formulae which describe them, are given for both males and females in Fig. 3.

The slope of the regression lines which represent the respective performances of the sexes is steeper for the female subgroup for all observation conditions. Also, it should be noted that female observers tend to produce more hits than male observers in their registration of pause. But the most notable difference of the separately fitted functions is that in all cases do the female observers generate data that can be plotted on a straight line, as is done in Fig. 3, whereas the male observers generate data that fall in a fairly tight cluster somewhere along or near to this line.

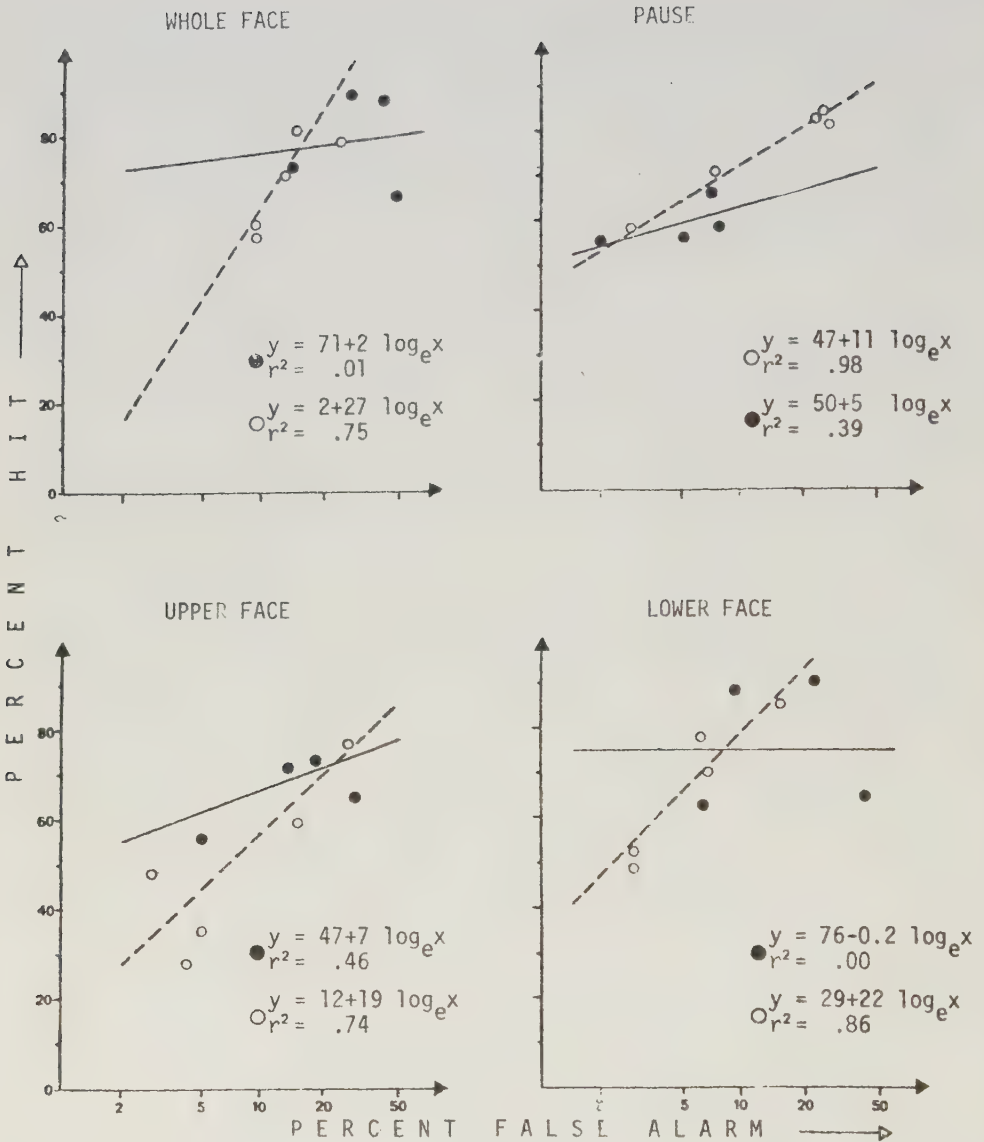


Fig. 3. Detection of infant facial behaviour by female (open circles) and male (filled circles) observers. Performance under four observation conditions is expressed as the percentage of "hits" relative to the (log) percentage of "false alarm" responses.

Correlation analyses of the data for the whole group of observers coded as hits and false alarms lead to some further interesting results. These are summarised in Table 4. The correlations for the false alarm responses are much higher in absolute values ($r_{\text{mdn}} = 0.8/$) than those for hits ($r_{\text{mdn}} = 0.5/$), and only two of the r_s 's for hit, U/P and U/L, reach significance at the 5% level, whereas all of the r_s 's for false alarm do, and all except P/U and P/L are significant beyond the 1% level. Thus, the false alarm rate typifies the individual observer better than does the hit rate. Interestingly enough, the order of individual values on the regression line is reversed in condition P relative to the other condition: Those observers who have a high hit/false alarm rate in condition W, U and L tend to have a low rate in condition P and vice versa (Table 4). It should be stressed that data are independent between conditions.

Table 4. Correlation coefficients between observation conditions based on individual rates of hit and false alarm responses, respectively.

Condition	Hit response			False response		
	P	U	L	P	U	L
W	-.39	.58	.40	-.90	.81	.83
P		-.63	-.44		-.71	-.71
U			.75			.81

The mean percent rates of hit and false alarm in the four conditions for the nine observers is shown in Table 5. The differences between the four observation conditions were tested separately for hit and false alarm in two Friedman two-way ANOVAs, resulting in $\chi^2_r = 12.6$, $p < 0.01$, for hit, and $\chi^2_r = 10.0$, $p < 0.02$, for false alarm. A breakdown analysis by Wilcoxon matched-pairs test showed significant differences between W and U, $p < 0.01$, for hit and between W and U, $p < 0.02$, and W and L, $p < 0.01$, for false alarm. The non-significant differences between W and P are,

probably due to the sizeable negative correlation between the scores from condition P and the scores from other conditions (cf. also Table 4).

Table 5. The mean percent hit and false alarm responses in the four observation conditions.

Condition:	W	P	U	L
Response				
Hit	73.6	62.1	56.8	70.4
False alarm	22.3	11.9	12.2	12.6

It was mentioned above that the observers differed in response styles, some generating many short responses while other produced fewer, longer responses. In order to get a better idea of these individual differences we made a count of all the very short responses (VSR), i.e. those having a duration shorter than one sec. Comparing the male and female observers by a Mann-Whitney U-test showed that the females made more VSR than the males ($N=9$, $U=1$, $p<0.02$). Employing the same procedure for each of the four observation conditions separately revealed a significant difference between male and female observers only in condition W ($N=9$, $U=0$, $p<0.01$). However, in all instances was the mean number of VSR higher for women than for men.

The positions of these VSR in the response distribution were ascertained for condition W. Out of 80 VSR occurring in this condition, 62 were made during the five secs. surrounding the beginning of signals (± 2.5 secs.) and only 18 at other points. Since there were 26 signals in the distribution, the time defined as occurring around the beginning of signals is 26 times five = 130 of the total of 345 secs. for the whole observation period. Thus, the VSR were clearly over-repre-

sented at the beginning of signals. The difference was due primarily to the contribution of the female observers, the responses of the males never differing very greatly from the expected value (Table 6).

Table 6. The number of very short responses (VSR) made by the nine observers in condition W.

Observers	♂1	♂2	♂3	♂4	♀1	♀2	♀3	♀4	♀5
Total VSR	6	2	0	6	15	12	19	13	7
Observed VSR around the beginning of signals	2	2	0	3	14	10	15	10	6
Expected VSR around the beginning of signals (Total $\times$ 130/345)	2.3	.8	0	2.3	5.7	4.5	7.2	4.9	2.6

D i s c u s s i o n

It may be impossible for different observers to reach a complete consensus in observation studies. Failure to do so has usually been attributed to errors of commission of specific items by observers (Hollenbeck, 1978). Disagreement between observers may also be due to a lack of synchronisation in their individual records. This is not only a problem of timing in a technical sense, i.e. discrepancies in the starting point and speed of recording, but also a question of the size of the subjective observation units employed by different observers. Disagreement among observers in their qualitative classification of behaviour (cf. Nyström, 1974) may also arise because of quantitative differences in the subjective size and location of the units to be retrieved and scored. Consequently, research should aim at having observers agree on the qualitative aspects of an observation before shortcomings in the classification scheme employed can be properly evaluated.

One of the primary aims of the experiment described above was

to discover the amount of quantitative variation present in observers' judgements of the presence or absence of the behaviour attended to. The results show a fairly high degree of consensus in this basic task. Thus, observers tended to make reasonably synchronous registrations which corresponded quite well to the points of activity in the video-recording of the infant's face, as shown by the fact that the response distribution closely resembled the signal distribution. It turned out that in cases where items defined in the signal distribution were omitted from the response distribution for the whole face condition (W), the items omitted were, almost without exception, of small physical magnitude irrespective of whether they occurred in the upper or lower half of the face.

By comparing the response distribution obtained from the part-face conditions, U and L, we can see that the observers succeeded in concentrating their attention on only one half of the infant's face and responding according to instructions. This may be shown most clearly by the strikingly low correlation between these two conditions as compared with their higher correlations with other conditions, which indicates that under the two sets of instructions, U and L, the observers did not respond to the same sets of behaviour. The correlations also indicate that, in general, the upper half of the face contributes less to the judged activity in the whole face than does the lower half. This is clearly related to the other result that there was significantly less judged activity in the upper half of the infant's face than in the lower half. It might also be argued that the reason is that the child observed was asleep with its eyes closed. Since, we know that the eyes are "the mirror of the soul", it might be said that being denied the view of this mirror the observers were less likely to look at that region

of the face, except when their attention was deliberately directed to it. And when this happened (condition U) the observers tended not to be much less accurate in their judgements than when they observed the lower half (condition L).

Regarding the summation of the two part-face conditions, it is not possible to say here with full certainty whether this gave more accurate information of what was happening in the infant's face than the whole-face condition. We should like to believe this, however, for the following reasons: The rises and falls of the combined curve ($U + L$) are generally steeper and more complete than those in the other curve (W). But it is also obvious that they describe the same activity since the correlation between them is high.

Another interesting aspect of the results is the way in which the observers responded at the points of transition from no-signal to signal and vice versa. It is here that the greatest amount of variation seems to occur. This is characterised on the individual response level by a greater amount of on-off responding, i.e. production of responses lasting less than one second (VSR), and in the pooled response distribution by a fairly slow rise and fall of the curve at the beginnings and ends of bursts of activity. The size of this "zone of uncertainty" can be estimated to be approximately ten percent of the signal length. But in addition to the greater amount of on-off responding, there is also the fact that some observers judged the activity to start earlier than others. One possible reason for the existence of this zone of uncertainty may be that some movement occurs in the infant's face which "heralds" the coming of the signal proper. (In other contexts this might be characterised as "intention movements"). The probability that something like this happens is enhanced by the fact that infants' facial movements do not occur as random muscular twitches, but

as units (cf. Oster, 1978) which, furthermore, are temporally organised relative to state of "arousal" (cf. Nyström, Bandmann & Valentin, 1977) and in terms of phasic integration (Nyström & Briem, in prep.). This implies that there exists in the sleeping child a "plan of action" which manifests itself in the observed sleep behaviour. How and why this happens we shall not attempt to explicate at this point.

In a similar way the gradual decrease of the response curve at the end of the burst of activity may reflect a property of the signal itself. Facial activity may decline gradually during a burst, causing a variation in the observers' judgement of the point in time when activity has stopped. This interpretation is consistent with the response curve obtained for condition P, which shows a greater consensus (steeper slope) about the end of the pause than there is about its beginning.

A good deal of the analysis of the results is done with similar methods to those used by signal detection theorists. However, it must be stressed that the use of these methods here amounts to little more than the borrowing of the terminology and methods of graphically representing data. Yet, this approach led, in our analysis, to the discovery of some interesting differences between male and female observers. Within the latter sex group there was evidence of greater gain in vigilance as responding increased. The male observers did not show this trend. The specific way in which this happened was that when the percentage "hit" and "false alarm" from the four observation conditions were plotted on single-log plots, the values generated by the female observers tended to lie on a straight line, whereas the values generated by the males tended to form a cluster. However, this does not necessarily indicate that the male observers are inferior to the female ones, only that they do not show the same kind of "lawfulness" in

their responding, i.e. there is not a very clear functional relationship between the two response classes (hit/false alarm)

This intriguing feature of the results requires further explanation. We can see from inspection of Fig. 3 (q.v.) that the male observers lie collectively somewhat higher in both "hits" and "false alarms" in conditions W, U and L than the female observers who, on the other hand, lie higher in both these response classes in condition P. The amounts of both "hits" and "false alarms" of the different observers are consistently correlated between conditions. Whether this trend portrays a general sex-difference or a specific individual trend cannot be decided with certainty because of the small sample size.

Regarding the correlations between "hit" and "false alarm" scores in the four observation conditions, it may be seen that these are considerably higher for "false alarm" than "hit", indicating that the "false alarm" rate, being more constant, is the better predictor of an observer's performance across conditions.

One possible explanation of the difference in response characteristics of male and female observers is that, irrespective of the stimulus material, female observers follow the instructions more strictly, while males adopt laxer criteria. Another interpretation is that females are especially motivated to detect changes in the behaviour of an infant while the male observers are not. A third explanation is that the females are, in general, more observant than the males (cf. Kirchner & Knapf, 1974). The latter two explanations are made the more plausible by the further findings in the experiment than the female observers did, on the average generate more of the very short response type (VSR) than the males did, indicating a greater

eagerness to respond and/or greater ability to detect minimal movements in the infant's face.

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*The Recording of Behavioural Data
with a Portable Data-Terminal*

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A b s t r a c t. - Discusses some of the methods employed and problems encountered in the registration and analysis of behaviour observational data. A registration system which relies on the use of a portable data terminal, MICRONIC 445, is described together with computer programs for sorting, editing, and analysing the data. It is argued that not only are the advantages associated with using electronic apparatus in behaviour observation considerable, but the use of this apparatus and associated techniques also makes possible new types of observation and analyses.

I n t r o d u c t i o n

The collection of data about an ongoing stream of behaviour is a task that has both fascinated and harassed behavioural scientists for centuries past. A review of the attempts to solve the problems involved in the observation of emotional expressions was presented by Charles Darwin more than 100 years ago (Darwin, 1965). The principal problem was then, as it still is, to identify and record meaningful behavioural events that could be classified in such a way as to fit into a system which exhaustively described the behaviour of the organism under observation. Darwin (op. cit.) gives a fascinating account of his own endeavours to classify and record many of the principal emotional expressions of people and animals, and his work provides the foundation for much modern work in the area, as has been duly recognised (cf. e.g. Ekman, 1973).

However, the problem stated above is rather a complex one, and should really be treated as two different problems: 1. Observation and data recording. 2. The creation of a behavioural taxonomy for the organism under study. These two problems are quite distinct, albeit closely related, and the relation between them is complementary. Thus, a behavioural taxonomy may well exist without methods for establishing the validity of the units of which it is composed, but such a taxonomy would be, at best, trivial. By the same token, a method for recording behavioural units would be of small value

without a description of their denotations as well as a set of rules for linking the units together.

In Darwin's time the study of taxonomic systems was already an established discipline (cf. e.g. Sneath & Socal, 1973, pp. 18-27), but systematic behavioural observation was still in its infancy. Indeed, Darwin was one of the pioneers in this field in that he attempted to introduce here the same scientific thoroughness and rigour as he had employed in his previous work. Most other students of behaviour at that time relied on intuition and ad hoc systems in their observations (cf. Darwin, op. cit.).

It was first with the advent of ethology in the early decades of the present century that significant progress began to be made in the field of behavioural observation. What the ethologists often used as units in their observations was the so-called fixed action patterns (FAPs), which are stereotyped behaviour elements exhibited by most animals. The FAPs are usually critical elements in goal-directed behaviour sequences. The taxonomies used were relatively simple: The animal's behaviour was usually first divided into two high-level categories which included the type of behaviour of interest to the ethologist, such as "courtship behaviour", on the one hand, and all other behaviour that the organism might engage in, on the other. The behaviour of interest was then divided into a small number of FAPs, the occurrence of which would be duly recorded. The usual recording equipment was pencil and paper.

As further progress was made in ethology and social psychology, the need for techniques which made possible more detailed studies of longer and shorter behavioural sequences began to be felt. This in its turn created the need for tighter organisation and planning of the studies in hand. These developments and similar ones in the biological sciences subsequently brought about renewed interest in numerical taxonomy, and since about 1960 there has been rapid development in this area (cf. Sneath & Socal, op. cit.). But these new trends showed, even more acutely, that in order to be able to obtain detailed behavioural data, the researcher would have to avail himself of accurate recording equipment. To begin with, the equipment used to support behaviour observation was limited to stopwatches and record sheets, the latter being carefully prepared beforehand for recording the occurrence of the behavioural categories under study. Later, mechanical, multi-channel-

ed event-recorders were brought into use. All the types of equipment mentioned above are still frequently used in behaviour observation (cf. Lehner, 1979; Sackett, 1978).

In the following pages I describe a behaviour observation system developed by myself and Dr. M. Nyström for use in our infant observation and other behaviour observation studies. The system involves the use of a portable data-terminal, an electronic device in which recorded data can be stored and from which they can later be retrieved. Two simple taxonomic systems for coding the observed data and computer programs for processing them are also described (Note 1).

M I C R O N I C 4 4 5 : C h a r a c t e r i s t i c s a n d a p p l i c a t i o n

With the microelectronic revolution the possibility of new, more efficient, and more accurate recording equipment was realised. At the beginning of the 1970s behavioural research workers began to avail themselves of electronic digital techniques in connection with data-registration and -analyses. This new automation in behavioural research methodology is described by e.g. Hollenbeck et al. (1975). To begin with, the researchers used the consoles of existing computer terminals for the input of observational data, but this, of course, limited the use to which the apparatus could be put. For instance, all studies which required direct input of data via the keyboard of the terminal had to be carried out in the laboratory where the terminal was situated. However, portable data-gathering terminals which were capable of transmitting the registered data to a host computer were soon to be developed. One of the first terminals of this type on the American market was DATAMYTE 900, a terminal which was suitable for behaviour observation. The use of this terminal in several behavioural experiments is documented in Sidowski (1977, pp. 403-455).

MICRONIC 445 is a Swedish made data-gathering terminal which is particularly well suited for behaviour observation and registration. This terminal was originally developed as an aid in product cataloging and warehouse stock-taking, but as the terminal is designed as a general purpose machine it has served very satisfactorily in several other contexts. The chief merit of

the terminal is its flexibility. It is capable of being programmed for several different applications, among them behaviour observation. A program for this purpose was first specified by Dr. G. Goude at Stockholm University, and a MICRONIC 445 was available in 1979 with a behaviour observation program written by C. Hillmering. An extension of this program was specified by the present author, programmed by Hillmering, and was available in 1980. This last routine, which enables the researcher to use the terminal as a 13-channel event-recorder, was designed so as to make it possible to register more effectively the kind of data described in Briem and Nyström (1978). (The recording instrument used in the experiment described in that paper was a 4-channel, mechanical event-recorder.)

Thus, three different recording modes are available for the MICRONIC 445 terminal: 1) "Occurrence" mode, where just the occurrence of a given item is recorded, 2) "timing" mode, where the time between two key-presses is recorded together with the code for the behaviour indicated by the first press, and 3) "event-recorder" mode, where the time for a particular behaviour is taken as long as the key corresponding to the behaviour code is held down. In this last mode, the time between key-presses is taken and indicated by a "null-code" ("0") which is generated by the terminal.

R e g i s t r a t i o n s y s t e m

The registration system is composed of two parts, firstly, information about the observed behaviour sequence, date of recording etc., collectively referred to as the "ID-code", and secondly, the coded sequence itself. These two parts are input successively and alternate in any series of observations. Thus, the first part of the input data is an ID-code which describes the relevant characteristics of the sequence of data which follows as a second part. At the end of that sequence, there may be another ID-code/data-sequence pair, and this pattern may repeat itself a number of times for any observation session. The occurrence mode is used to enter the ID-code.

Below, the use of the system with two, alternative, simple taxonomies is shown. In the first one, the terminal is used as a 1-channel event-recorder, where the data recorded are "behaviour" and "absence of behaviour" (event-recorder mode). In the second taxonomy, there are 8 categories which contain

various types of activity, the occurrence and duration of which is recorded in the terminal (timing mode).

ID-code: The ID-code used for both the taxonomies is the same. It has three, hierarchically arranged levels. The first level, which need only be used once for a given series of observations, contains an identification of the study and the date when the observation took place. The second level contains film number and starting point (specified only for filmed material) as well as a code number specifying the taxonomic system used in the observation sequence that follows. The third level, specified for all sequences, contains observer number, the number of the focal person (or animal), and the starting time of the observation sequence (24-hour format). Thus the top level of the code is specified only once for any series of observations, the middle level when necessary, and the lowest level for every sequence in a series. This hierarchical arrangement makes it considerably easier to use the code efficiently.

A schematic representation of the ID-code is given in Table 1. The top level in the code is designated by an `A`, the middle level by a `B`, and the lowest level by a `C`. The beginning of a code-level is indicated by an `EE` and the end by an `E`.

Table 1: The lay-out of the ID-code. Each `X` stands for one digit.

Level of ID-code	Format
A	EE A XX XXXXXX E
B	EE B XX XX XX E
C	EE C XX XX XXXX E

The `E` at the end of the level-C code represents also the beginning of a registration sequence which always ends with an `EE`, and may be followed by another C (or B-C or A-B-C) code and another registration sequence, or nothing at all which then signifies the end of the observation series. `EE` and `E` are generated automatically by the machine when the buttons marked `INGRESS` and `START` are pressed.

Taxonomic systems: In order to illustrate the system described here, two taxonomic systems for data generated in each of the two MICRONIC 445 observation modes are shown. The first one (A) was developed for observation of neonatal facial behaviour in the "event-recorder" observation mode, while the second one (B) is at present being used in the observation and analysis of the work-time activities of VDU/telecom operators (Note 2). Observation here is in the timing mode.

- A/ The system is a dichotomic one, designed for the registration of occurrence or non-occurrence and duration of the behaviour under observation (cf. Briem & Nyström, op. cit.). Only two codes are used, `0` and `1`. In the event-recorder mode, 0 is generated by the machine, and represents "no key-press", i.e. the time taken for this code is the time between key-presses. 1 is the number keyed in by the observer, and represents "behaviour". The time taken for 1 is the time that this key has been held down. For example, the sequence `0 9 1 22 0 15 1 23 .....` begins with a .9 seconds` absence of behaviour, followed by 2.2 seconds` facial behaviour, followed by 1.5 seconds` absence of behaviour etc. The times given by the terminal are in 1/10 seconds, and all codes and times are separated by a space.
- B/ In this system, the activities of the operators are grouped into 8 distinct, non-overlapping, and exhaustive categories. Four of these contain activities at the VDU, while the other 4 are activities which are not directly involved in the job such as e.g. social interaction. The taxonomy is, of course, tailored to fit the study in hand. The codes used here are `1` - `8` which are keyed in by the observer. In this mode the machine does not generate any null-codes, only the times between key-presses, and the keys do not need to be held down while the time for the duration of the relevant code is being taken. This system and the study in which it is employed are described in more detail in a forthcoming report.

At the end of a series of observations the data are transferred to the host computer, in this case a Univac 1100/80, via a direct link or a modem and telephone link. The transfer is guided by the experimenter on a computer terminal. Details of the transfer operation and other aspects of the use of the MICRONIC 445 terminal can be found in the User`s Manual (1979).

Figure 1 shows a print-out of an unsorted MICRONIC-data file transferred to the host computer. It contains data generated according to a dichotomic observation system (system (A) above). The data can subsequently be sorted, edited, and then saved for later analyses, or input directly into one of the analytic programs written for this type of data.

```

1
2 EEDAD01D800619DE EEDBD01D01D01DE EEDCD1314D01DE 0 28 1 39 0 29 EEDCD1316D01DE 0
3 16 1 308 0 12 1 67 0 38 1 21 0 21 1 10 0 64 1 63 0 4 1 16 0 9 1 117 0 12 1 111 0
4 14 1 30 0 76 1 28 0 39 1 33 0 18 1 66 0 14 1 33 0 14 1 13 0 62 1 95 0 9 1 58 0
5 34 1 104 0 3 1 14 0 14 1 6 0 62 1 23 0 38 1 80 0 11 1 14 0 16 EEDCD1321D02DE 0 1
6 3 1 314 0 9 1 61 0 15 1 17 0 11 1 18 0 22 1 21 0 11 1 17 0 23 1 83 0 15 1 18 0 1
7 3 1 32 0 108 1 69 0 10 1 14 0 10 1 103 0 46 1 24 0 35 1 50 0 61 1 33 0 47 1 100
8 0 12 1 54 0 25 1 142 0 133 1 45 0 5 1 17 0 41 EEDCD1330D03DE 0 7 1 313 0 12 1 63
9 0 33 1 26 0 23 1 13 0 60 1 22 0 7 1 9 0 19 1 25 0 22 1 13 0 19 1 181 0 37 1 71
10 0 11 1 42 0 37 1 32 0 30 1 52 0 19 1 17 0 28 1 20 0 45 1 170 0 34 1 74 0 4 1 28
11 0 14 1 25 0 62 1 12 0 43 1 91 0 26 EEDCD1338D04DE 0 9 1 315 0 10 1 124 0 26 1 9
12 0 60 1 52 0 35 1 119 0 63 1 49 0 33 1 160 0 7 1 12 0 48 1 55 0 13 1 29 0 18 1 11
13 0 57 1 173 0 20 1 83 0 17 1 70 0 58 1 9 0 32 1 98 0 14 EEDCD1353D01DE 0 26 1 29
14 5 0 15 1 15 0 4 1 45 0 35 1 25 0 19 1 11 0 64 1 24 0 4 1 15 0 12 1 24 0 8 1 81 0
15 190 EE
16 EECE 0 177 EEC2E 0 15 1 64 0 69 EEC3E 0 15 1 307 0 8 1 81 0 25 1 22 0 94 1 6 0 5
17 0 1 16 0 23 1 27 0 14 1 4 0 15 1 13 0 6 1 23 0 21 1 5 0 44 1 19 0 12 1 14 0 39 1
18 10 0 6 1 30 0 3 1 54 0 4 1 28 0 30 1 30 0 26 1 54 0 20 1 33 0 14 1 14 0 46 1 8
19 0 9 1 91 0 13 1 32 0 9 1 7 0 37 1 31 0 8 1 51 0 6 1 29 0 5 1 31 0 102 1 28 0 5 1
20 38 0 28 1 8 0 6 0 26 EE
END OF FILE

```

Figure 1: Unsorted MICRONIC 445 data. EE marks the beginning of an ID-code, and E the end. D is a filler. A, B, and C mark the three levels of a three-tiered hierarchical code. The free-format data lie between E and EE, 0 and 1 are behaviour codes, and the times indicated after these are in 1/10 sec. units.

Computer programs

In order to be able to use the data gathered with the terminal and transmitted to the host computer effectively, there must exist suitable computer programs for processing the data. Several programs written by the author for this purpose are available. The first of these, (ORDER, written in CTS, cf. below) is a general program for sorting and editing the data from the terminal and restoring it to a format which can, more or less directly, be input into analytic programs for further processing. The second program (CAL, written in Simula) is a specific, analytic program which gives maxima, minima, behaviour-code durations, and various other descriptive features of the input data. A third program (COR, written in Simula) is also available

for simple auto- and cross-correlations of observation sequences. The use of the first two programs with the observation data shown in Figure 1 is illustrated below (Note 3).

Program 1, ORDER: CTS (Conversational Time-Sharing System. Cf. SPERRY UNIVAC 1100 Series, 1977), while being in a sense an extension of the operative system of the Univac 1100 series of computers, providing "an interactive interface for users of the system", is also a low-level programming language. It offers an easy and effective means of creating and editing programs and data-files. The editing functions can be put under program control, as can also simpler logical and arithmetic operations. It is in this language that ORDER is written.

Above, I described a system for registering behavioural data, storing it temporarily, and then moving it to a data file in the host computer's memory. Once the data are there, they can be accessed, sorted, and edited with CTS instructions. This is necessary as the data, when they first arrive to the computer, are composed of data which are to be used and data which are unusable for some reason: ID-codes and behavioural data codes and recorded durations may be broken up and divided between consecutive lines (this would be interpreted by the computer as two different numbers, instead of just one), control variables for statistical analyses are missing, and so on. In other words, the data must be sorted and edited before they can be used.

ORDER accesses a file of MICRONIC data, sorts out ID-codes and behaviour data, and places these on separate lines in a new data file. ID-codes and other data which were divided between lines in the file when they were transferred to the computer are joined together again. In the resulting data file, each level of the ID-code occupies its own line, and the data for each behaviour sequence lie parcelled together (Figure 2).

But further editing may be necessary. "Rubbish" such as faulty codes, false starts, and parts of observation sequences which have not been completed must be removed. This part of the editing must be done manually as the computer is generally unable to discriminate between "proper data" and "garbage". The file edited in this way is shown in Figure 3.

```

100 EE A 01 800619 E
110
120 EE B 01 01 01 E
130
140 EE C 1314 01 E
150 0 28 1 39 0 29
160 EE C 1316 01 E
170 0
180 16 1 308 0 12 1 67 0 38 1 21 0 21 1 10 0 64 1 63 0 4 1 16 0 9 1 117 0 12 1 111 0
190 14 1 30 0 76 1 28 0 39 1 33 0 18 1 66 0 14 1 33 0 14 1 13 0 62 1 95 0 9 1 58 0
200 34 1 104 0 3 1 14 0 14 1 6 0 62 1 23 0 38 1 80 0 11 1 14 0 16
210 EE C 1321 02 E
220 0 13
230 1 314 0 9 1 61 0 15 1 17 0 11 1 18 0 22 1 21 0 11 1 17 0 23 1 83 0 15 1 18 0 13
240 1 32 0 108 1 69 0 10 1 14 0 10 1 103 0 46 1 24 0 35 1 50 0 61 1 33 0 47 1 100
250 0 12 1 54 0 25 1 142 0 133 1 45 0 5 1 17 0 41
260 EE C 1330 03 E
270 0 7 1 313 0 12 1 63
280 0 33 1 26 0 23 1 13 0 60 1 22 0 7 1 9 0 19 1 25 0 22 1 13 0 19 1 181 0 37 1 71
290 0 11 1 42 0 37 1 32 0 30 1 52 0 19 1 17 0 28 1 20 0 45 1 170 0 34 1 74 0 4 1 28
300 0 14 1 25 0 62 1 12 0 43 1 91 0 26
310 EE C 1338 04 E
320 0 9 1 315 0 10 1 124 0 26 1 9
330 0 60 1 52 0 35 1 119 0 63 1 49 0 33 1 160 0 7 1 12 0 48 1 55 0 13 1 29 0 18 1 11
340 0 57 1 173 0 20 1 83 0 17 1 70 0 58 1 9 0 32 1 98 0 14
350 EE C 1353 01 E
360 0 26 1 295
370 0 15 1 15 0 4 1 45 0 35 1 25 0 19 1 11 0 64 1 24 0 4 1 15 0 12 1 24 0 8 1 81 0
380 190
390 EE E
400 ECE 0 177
410 EEC2E
420 0 15 1 64 0 69
430 EEC3E
440 0 15 1 307 0 8 1 81 0 25 1 22 0 94 1 6 0 50
450 1 16 0 23 1 27 0 14 1 4 0 15 1 13 0 6 1 23 0 21 1 5 0 44 1 19 0 12 1 14 0 39 1
460 10 0 6 1 30 0 3 1 54 0 4 1 28 0 30 1 30 0 26 1 54 0 20 1 33 0 14 1 14 0 46 1 8
470 0 9 1 91 0 13 1 32 0 9 1 7 0 37 1 31 0 8 1 51 0 6 1 29 0 5 1 31 0 102 1 28 0 5 1
480 38 0 28 1 8 0 6 0 26
END OF FILE

```

Figure 2: The sample data sorted with the program ORDER.

```

100 EE A 01 800619 E
110
120 EE B 01 01 01 E
130
160 EE C 1316 01 E
170 0
180 16 1 308 0 12 1 67 0 38 1 21 0 21 1 10 0 64 1 63 0 4 1 16 0 9 1 117 0 12 1 111 0
190 14 1 30 0 76 1 28 0 39 1 33 0 18 1 66 0 14 1 33 0 14 1 13 0 62 1 95 0 9 1 58 0
200 34 1 104 0 3 1 14 0 14 1 6 0 62 1 23 0 38 1 80 0 11 1 14 0 16
210 EE C 1321 02 E
220 0 13
230 1 314 0 9 1 61 0 15 1 17 0 11 1 18 0 22 1 21 0 11 1 17 0 23 1 83 0 15 1 18 0 13
240 1 32 0 108 1 69 0 10 1 14 0 10 1 103 0 46 1 24 0 35 1 50 0 61 1 33 0 47 1 100
250 0 12 1 54 0 25 1 142 0 133 1 45 0 5 1 17 0 41
260 EE C 1330 03 E
270 0 7 1 313 0 12 1 63
280 0 33 1 26 0 23 1 13 0 60 1 22 0 7 1 9 0 19 1 25 0 22 1 13 0 19 1 181 0 37 1 71
290 0 11 1 42 0 37 1 32 0 30 1 52 0 19 1 17 0 28 1 20 0 45 1 170 0 34 1 74 0 4 1 28
300 0 14 1 25 0 62 1 12 0 43 1 91 0 26
310 EE C 1338 04 E
320 0 9 1 315 0 10 1 124 0 26 1 9
330 0 60 1 52 0 35 1 119 0 63 1 49 0 33 1 160 0 7 1 12 0 48 1 55 0 13 1 29 0 18 1 11
340 0 57 1 173 0 20 1 83 0 17 1 70 0 58 1 9 0 32 1 98 0 14
END OF FILE

```

Figure 3: The sample data after false starts (lines 140-150, 350-380) and erroneous data (lines 390-480) have been taken out.

As the file now contains only useful data, it can be saved. At a later date it may be merged with other files of the same type, or used as data in some analytic program, after the ID-codes have been exchanged for or complemented with the appropriate control variables. Figure 4 shows the edited data file with these variables inserted.

```

150 4 250
160 1 1
170 0
180 16 1 308 0 12 1 67 0 38 1 21 0 21 1 10 0 64 1 63 0 4 1 16 0 9 1 117 0 12 1 111 0
190 14 1 30 0 76 1 28 0 39 1 33 0 18 1 66 0 14 1 33 0 14 1 13 0 62 1 95 0 9 1 58 0
200 34 1 104 0 3 1 14 0 14 1 6 0 62 1 23 0 38 1 80 0 11 1 14 0 16
210 1 0 999 1 2
220 0 13
230 1 314 0 9 1 61 0 15 1 17 0 11 1 18 0 22 1 21 0 11 1 17 0 23 1 83 0 15 1 18 0 13
240 1 32 0 108 1 69 0 10 1 14 0 10 1 103 0 46 1 24 0 35 1 50 0 61 1 33 0 47 1 100
250 0 12 1 54 0 25 1 142 0 133 1 45 0 5 1 17 0 41
260 1 0 999 1 3
270 0 7 1 313 0 12 1 63
280 0 33 1 26 0 23 1 13 0 60 1 22 0 7 1 9 0 19 1 25 0 22 1 13 0 19 1 181 0 37 1 71
290 0 11 1 42 0 37 1 32 0 30 1 52 0 19 1 17 0 28 1 20 0 45 1 170 0 34 1 74 0 4 1 28
300 0 14 1 25 0 62 1 12 0 43 1 91 0 26
310 1 0 999 1 4
320 0 9 1 315 0 10 1 124 0 26 1 9
330 0 60 1 52 0 35 1 119 0 63 1 49 0 33 1 160 0 7 1 12 0 48 1 55 0 13 1 29 0 18 1 11
340 0 57 1 173 0 20 1 83 0 17 1 70 0 58 1 9 0 32 1 98 0 14
490 1 0 999
END OF FILE

```

Figure 4: The sample data which have now been prepared for analysis in the program CAL. Control variables have been substituted for the ID-codes. The variables in line 150 specify the number of data sets to be analysed and the maximum length of observation time.

Program 2, CAL: This program is intended for calculations of descriptive statistical properties of the data collected with MICRONIC 445 in the manner described above. The output is primarily of two kinds: (1) Various statistical characteristics of the data, such as the maximum, minimum, and average length of the "bursts" of behaviour under observation and the "pauses" (i.e. absence of the behaviour) in between these bursts. (2) A graphic summary of several observations by the same or different observers of the same behaviour sequence. The output from CAL with our sample data as input is shown in Figure 5.

The program accepts behavioural data in free format (every number separated from every other by a space). The data must also be of the format b(1) t(1) b(2) t(2) b(3) t(3) b(i) t(i) b(n-1) t(n-1) b(n)

```

RESULTS FROM BEHAVIOUR OBSERVATION SERIES REM-SLEEP
NUMBER OF OBSERVATION SEQUENCES = 4

RESULTS FROM OBSERVATION SEQUENCE 1001
TOTAL OBSERVATION TIME = 191.00 SECONDS
NUMBER OF KEY-PRESSES = 25
PERCENTAGE OF TIME WHERE BEHAVIOUR WAS OBSERVED = 60.59%
MEAN LENGTH OF BURSTS OF BEHAVIOUR = 5.95 SECONDS
MEAN LENGTH OF PAUSES BETWEEN BURSTS OF BEHAVIOUR = 2.61 SECONDS
NUMBER OF VSR = 1
* MAX. = 30.00 , MIN. = 0.60 , S.D. = 6.43 *
* MAX. = 7.60 , MIN. = 0.30 , S.D. = 2.10 *

RESULTS FROM OBSERVATION SEQUENCE 1002
TOTAL OBSERVATION TIME = 189.70 SECONDS
NUMBER OF KEY-PRESSES = 20
PERCENTAGE OF TIME WHERE BEHAVIOUR WAS OBSERVED = 64.94%
MEAN LENGTH OF BURSTS OF BEHAVIOUR = 6.16 SECONDS
MEAN LENGTH OF PAUSES BETWEEN BURSTS OF BEHAVIOUR = 3.17 SECONDS
NUMBER OF VSR = 0
* MAX. = 31.40 , MIN. = 1.40 , S.D. = 6.75 *
* MAX. = 13.30 , MIN. = 0.50 , S.D. = 3.20 *

RESULTS FROM OBSERVATION SEQUENCE 1003
TOTAL OBSERVATION TIME = 189.10 SECONDS
NUMBER OF KEY-PRESSES = 21
PERCENTAGE OF TIME WHERE BEHAVIOUR WAS OBSERVED = 68.69%
MEAN LENGTH OF BURSTS OF BEHAVIOUR = 6.19 SECONDS
MEAN LENGTH OF PAUSES BETWEEN BURSTS OF BEHAVIOUR = 2.69 SECONDS
NUMBER OF VSR = 0
* MAX. = 31.30 , MIN. = 0.90 , S.D. = 7.30 *
* MAX. = 6.20 , MIN. = 0.40 , S.D. = 1.57 *

RESULTS FROM OBSERVATION SEQUENCE 1004
TOTAL OBSERVATION TIME = 188.80 SECONDS
NUMBER OF KEY-PRESSES = 16
PERCENTAGE OF TIME WHERE BEHAVIOUR WAS OBSERVED = 72.46%
MEAN LENGTH OF BURSTS OF BEHAVIOUR = 8.55 SECONDS
MEAN LENGTH OF PAUSES BETWEEN BURSTS OF BEHAVIOUR = 3.06 SECONDS
NUMBER OF VSR = 0
* MAX. = 31.50 , MIN. = 0.90 , S.D. = 7.83 *
* MAX. = 6.30 , MIN. = 0.70 , S.D. = 1.91 *

A SUMMARY OF RESULTS FROM OBSERVATION SEQUENCES 1001 - 1004
MEAN OBSERVATION TIME = 189.65
MEAN NUMBER OF KEY-PRESSES = 19.75
MEAN PERCENTAGE OF TIME FOR BURSTS OF BEHAVIOUR = 68.67%
MEAN LENGTH OF BURSTS OF BEHAVIOUR = 6.71 SECONDS
MEAN LENGTH OF PAUSES BETWEEN BURSTS OF BEHAVIOUR = 2.88 SECONDS
MEAN NUMBER OF VSR = 0.25
* MAX. = 22.00 , MIN. = 16.00 , S.D. = 2.28 *
* MAX. = 72.46 , MIN. = 64.94 , S.D. = 2.66 *
* MAX. = 31.50 , MIN. = 0.60 , S.D. = 1.06 *
* MAX. = 13.30 , MIN. = 0.30 , S.D. = 0.24 *
* MAX. = 1.00 , MIN. = 0.00 , S.D. = 0.43 *

```

Figure 5: The output from CAL. The output is in three parts: 1) Results from 4 individual observation sequences, each of the same behaviour, the same start, and approx. the same end point. (VSR = Very Short Responses, i.e. shorter than 1 sec.). 2) Summary of all 4 sequences. 3) Graphic summary which simulates the output from a mechanical event recorder and puts up a histogram of the output. Each star represents behaviour observed for $>\frac{1}{2}$ sec. period.

GRAPHIC SUMMARY OF RESULTS FROM OBSERVATION SERIES REM-SLEEP, SEQUENCES 1001 - 1004

SECONDS	OBSERVATION SEQUENCE-NUMBER							
	1	2	3	4				
1					84			0000
2					85			0000
3					86			0000
4					87			0000
5					88			00
6					89			00
7					90			
8					91			0000
9					92			00
10					93			0000
11					94			00
12					95			000
13					96			000
14					97			000
15					98			00
16					99			000
17					100			000
18					101			000
19					102			0000
20					103			0000
21					104			00
22					105			00
23					106			00
24					107			00
25					108			000
26					109			00
27					110			00
28					111			00
29					112			00
30					113			00
31					114			0000
32					115			0000
33					116			0000
34					117			0000
35					118			0000
36					119			00
37					120			
38					121			00
39					122			00
40					123			00
41					124			00
42					125			000
43					126			0000
44					127			00
45					128			00
46					129			
47					130			
48					131			00
49					132			000
50					133			0000
51					134			0000
52					135			0000
53					136			0000
54					137			0000
55					138			0000
56					139			0000
57					140			0000
58					141			0000
59					142			0000
60					143			00
61					144			000
62					145			0000
63					146			0000
64					147			0000
65					148			0000
66					149			000
67					150			
68					151			
69					152			000
70					153			000
71					154			0000
72					155			0000
73					156			0000
74					157			0000
75					158			0000
76					159			000
77					160			000
78					161			000
79					162			0000
80					163			000
81					164			0000
82					165			0000
83					166			00
					167			00
					168			00
					169			00
					170			
					171			
					172			
					173			
					174			00
					175			00
					176			00
					177			00
					178			00
					179			00
					180			0000
					181			0000
					182			0000
					183			0000
					184			0000
					185			0000
					186			0000
					187			00
					188			00
					189			00
					190			00
					191			00

Figure 5 (cont.)

$t(n)$, where b is the code for the behaviour observed and t is the length of time for that burst of behaviour. In our example, the codes are '0' for a pause and '1' for a burst of behaviour. 0 and 1 always appear one after the other in pairs together with their durations. This entails that the b/t pairs with odd numbers in the sequence are pause and its duration, and the even pairs are behaviour and its duration. The data are automatically re-registered in this form by MICRONIC 445 in event recorder mode.

Yet another requirement for the use of the program is that the data in the input file have certain control variables in critical places which contain information such as e.g. the number of data sets to be analysed and the maximum length of time for any sequence. The data file shown in Figure 4 has 4 useable data sets each with a maximum duration of 250 seconds.

The output shown in Figure 5 begins with a general heading identifying it. The rest is in three parts: (1) A summary of each sequence individually. (2) A summary of all the sequences together. (3) A graphic summary of the sequences, individually and summed together in a histogram, where the sequence is broken up and shown as 1-second units on the time-scale. Part 2 and the histogram in part 3 are meaningful only if the observations in the series are of the same behaviour sequence and if all the observations have the same starting point in the sequence.

THE USEFULNESS OF DATA-COLLECTION TERMINALS AND COMPUTERS IN BEHAVIOUR OBSERVATION AND ANALYSIS

Before the advent of microelectronic apparatus and computing technology, the observation of sequences of behaviour was, because of the practical difficulties involved, a forbidding enterprise that only attracted researchers with endless patience and dedication. Even then, these courageous students of behaviour were quite restricted in the type of observation and analysis that they could carry out. For example, time-series analyses of behaviour require exact and reliable measurements of onsets and cessations of behavioural activities, and, furthermore, large quantities of these behavioural measurements are needed in order that reliable analyses and predictions of future behaviour can be made. An investigator with only a stop-watch and pencil

and paper to aid him will soon give up in frustration with the ardour of the task of trying to put on record the sequence and durations of different behavioural elements. Even with a film of the behaviour of interest to look at repeatedly, maybe at different speeds, the task is well nigh impossible. If the same investigator tackles the problem with the aid of a mechanical event-recorder, he immediately stands a better chance. Now he can, at least, record the behaviour sequences, that he is interested in. But having solved that problem, he is now confronted with the one of decoding his records, a time-consuming and difficult task. And when he has spent several weeks in that activity he has at last come to the problem of doing a time-series analysis of the data. This task is also a demanding one. Although the statistical calculations involved are not very complicated, it is difficult, even with a small data-set, to compute the interdependencies between events that occur at different points in time. The result was usually that no real time-series analysis was carried out, but some sort of compromise was implemented instead, such as a Markov chain analysis or a grouping of the behaviour elements by cluster analysis. These types of analyses have the disadvantage that they can only identify fixed groups of behaviour units, and not the more intricate sequential dependencies of the elements.

When the electronic computer became available, complex time-series analysis of large behavioural data-sets also became a possibility. And the appearance of the portable data-collection terminal on the scene made it a viable enterprise to generate accurately the large amounts of data needed and to pass them on to the computer for analysis. Thus, the opportunity now exists for detailed analysis of behaviour. It is left up to the creative and ambitious researcher to collect and analyse the data with the appropriate methods, and then come to some ingenious conclusions about the results.

Several observation systems, similar to the one presented here, have been developed by other investigators during the past few years. Some systems particularly relevant to the DATAMYTE 900 terminal have already been mentioned (Sidowski, op. cit.). Hollenbeck et al. (op. cit.) presented a system for registering behaviour observation data on a Teletype 30 terminal, storing the data on paper tape, wherefrom it was subsequently fed into the host computer. Hollenbeck et al. (1977) then presented an extended and improved version of the system. Sackett et al. (1979) described a statistical method, "lag sequential analysis", for calculating temporal dependencies in behav-

journal data and presented a FORTRAN program that will take care of the calculations. Smith and Begeman (1980) presented a general system for collecting and editing structured DATAMYTE data. Flowers (1982) presents a similar, laboratory-bound system for the APPLE II. Indeed, the whole of SESSION XIII of the 11th National Conference on the Use of On-Line Computers in Psychology was devoted to problems encountered in this area (Sidowski, 1982, pp. 227-252).

But methodological advances alone are not a sufficient guarantee of valid results from behaviour observational studies, even if the improved methods are bound to contribute to a greater reliability of the studies. Hinde (1982, pp. 30-32) points out that there are considerable problems involved in the description of behaviour. He distinguishes two methods of description, "physical description" and "descriptions by consequence". Considering the two taxonomic systems presented above, it would seem obvious that taxonomy A) employs physical description and B) description by consequence. Both of these two types of description are equally valid, but each has characteristic pitfalls associated with it. Thus, if one chooses to employ the first alternative, one is liable to overlook the functional equivalence of many of the observed actions, whereas looking only at the consequences of a certain behaviour may obscure alternative interpretations of the significance of the action performed. But the type of description which guides the construction of the a priori taxonomy used in an observation study is often dictated by the nature of the investigation at hand. Therefore, in such cases one can do no better than to be aware of the possible errors that one may commit, and do one's best to avoid making them.

Note 1: "Taxonomy" and "taxonomic system" as used in these pages usually denote a system designed for describing and registering the behaviour observed, a system designed as an aid in systematic observation, an "a priori taxonomy". This is in contrast to the usage of the term by Sneath & Socal (op. cit.), where the term usually refers to a classification system derived by numerical methods from observed units, i.e. an "a posteriori taxonomy". This distinction is fundamental, and will be discussed in more detail elsewhere.

Note 2: "VDU" is a standard abbreviation for a "Visual Display Unit", sometimes also referred to as a "CRT" ("Cathode Ray Tube"). "Telecom" stands for "telecommunication". The physical environment and type of work done by the operators is described in Hedman & Briem (1983), "Changes in Focusing Accuracy of VDU-Operators as a function of Age, Hours Worked, and Task." This paper has been submitted for publication.

Note 3: I did not consider it appropriate to include here listings of the computer programs described in this paper, specially as they are at the moment, being revised. The programs will soon be available in a more general and extended version. However, I shall gladly supply listings to anyone interested in obtaining the programs in their present form.

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PSYCHOLOGICAL RESEARCH BULLETIN

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*Application of Behaviour Observation for Investigating
Relative Work Content, Behavioural Style, and
Social Interaction in Telecom Work*

1. Behavioural Taxonomy

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A b s t r a c t. - Observed video-taped sequences of the work behaviour of 9 telecom operators at a Swedish telecom centre and registered the behaviour of the operators with a portable data-terminal according to an a priori behavioural taxonomy devised for this purpose. The results of analyses of the observational data indicate that there exists a strong task component in the relative work content as well as an individual component which renders each of the operators' work content profile unique. It is concluded that behaviour observation, both conceptually and as a methodology, is very well suited for job analysis, especially as it allows registration not only of task related behaviour but also of social components in the work situation.

I n t r o d u c t i o n

Analysis of work content is an established practice in industrial and organizational psychology (cf. Howell & Dipboye, 1982, Ch.6). The purpose of the analysis is often to discover the functional parts of which the job in question consists, usually with the aim of increasing the efficiency of work methods or job instruction. Modern studies in this area may be said to have begun with the 'scientific management' studies of F.W. Taylor (Taylor, 1911). The time-and-motion study methodology that Taylor introduced soon became impopular among the workers subjected to it, who saw it as a tool for their exploitation, but correspondingly popular among the industrialists, who saw it as a means of increasing productivity and thereby profits.

Whatever the ultimate objective of work studies, it is clear that they are potentially a means of heightening work efficiency, especially when the work consists mainly of relatively uncomplicated manual skills. They are also a means of bringing clarity into the internal job composition, thus facilitating job design and instruction. Work content analysis goes under various names depending on the way the analysis is carried out, in what parts of the job situation one concentrates the study, as well as the organizational philosophy one has adopted. Technological development also deter-

mines what methods are available at a given time and what sort of results one can obtain.

Social interaction and group formation in organizational settings have often been studied with such methods as sociometry (cf. e.g. Moreno & Jennings, 1938) and network analysis (Shaw, 1976; Tichy & Fombrun, 1979). By the use of methods such as these it has repeatedly been shown how workers' group formation, behaviour, and communication constitute a major factor in organizational effectiveness (Howell & Dipboye, 1982).

Behaviour observation is a technique which has its origins primarily in animal studies, and its development is closely related to that of the scientific discipline of ethology (cf. Sackett, 1978). This research method has not previously been used much in studies of practical skills, but the state of the art has now reached such a level as to allow its introduction into this field of study. For example, Hoecker (1981) describes two studies in which methods similar to those employed for behaviour observation are used for collecting data about office work behaviour, and Hoecker (1982) reports the use of behavioural correlates in the analysis of performance in a problem solving task. Behaviour observation techniques have also been employed in various other situations where interpersonal interaction, verbal or non-verbal, occurs, e.g. for sampling police activities and interactions in the field, and informal group formation of naval personnel (Sykes, 1977), or for studying teacher-pupil interaction in the classroom (Crossman et al., 1978). The procedures employed here always involve the coding of specific behavioural units, with ensuing registrations and analyses of behavioural contingencies.

In order to achieve effective coding of the behaviour under observation, a representative a priori behavioural taxonomy must exist. The taxonomy may effectively represent only a small segment of an individual's behaviour, such as the behaviour occurring in a classroom or an office, but any behaviour belonging in that individual's behavioural repertoire must be capable of being represented in the registration.

A taxonomic representation of a particular job implies breaking it down into its components. The components, or units of analysis, of which the job is composed can then be referred to as 'operations' or 'actions'. The job may

now be further represented as a nested hierarchy of operations. A system of this kind has been presented in connection with a procedure called 'task analysis' which has been used mainly in the development of training schemes (Annett, 1978). This method of representing a particular job may be contrasted to the method of 'skills analysis' (Seymour, 1966). The latter method, which is derived from time-and-motion study, aims at describing the task under analysis as a sequence of related actions. It constitutes, therefore, a linear representation of the job.

The study reported in the present paper describes the observation, registration, and subsequent analysis of the work behaviour of operators at Televerket's telecom centre in Malmö. (A previous study of telecom operators' visual function with respect to a number of variables is described in Hedman & Briem (1984). This report contains a more detailed account of the operators' job environment than the one given in the present paper.) The coding system used was developed partly through direct observation of the operators at work, and partly through interviews with personnel at the telecom centre. Relevant information was also obtained from a report of a "frequency study" carried out some years previously at another Swedish telecom centre (Televerket, 1974).

Several different objectives were defined for the study. These are (1) to discover the relative proportions of actual telecom work and other job components, including social interaction, that occurred during the time that the operators were in the job situation, (2) to compare relative work content for work in computer data-based telecom work with conventional hard-copy directory telecom work, as well as (3) to test the effectiveness of behaviour observation methodology in the investigation of these factors.

M e t h o d

Background

A number of operators at Televerket's telecom centre in Malmö were video-filmed during their work in number and name information service. An AKAI portable cassette videotape-recorder, black/white, was used for this purpose. An external microphone was used to pick up the operators' conversations. Operators were filmed on a number of occasions under two consecutive weeks during work in (1) computer data based telecom work and (2) conventional hard-copy directory based telecom work. These two works' conditions are

referred to as VDU and MAN, respectively, and are described in detail in Hedman & Briem (1984). Seven videofilms were chosen for the analysis of operator behaviour. Six of those were of single operators in the VDU condition, while the seventh was of a group of operators working together in the MAN condition.

Behavioural taxonomy

A taxonomy of "telecom operator behaviour" was devised according to the principles laid down for such constructions (cf. Briem, 1983). This a priori taxonomy is shown in Figure 1. It is a hierarchical structure, in fact a symmetrical binary tree (cf. e.g. Horowitz & Sahni, 1978), containing 8 behavioural categories. In order to make the registration easier, two additional categories were incorporated. These two categories were then used as "markers", one for the end of an established connection with a client, the other for a "time out" period, where the behaviour of the focal operator could not be coded according to the taxonomy.

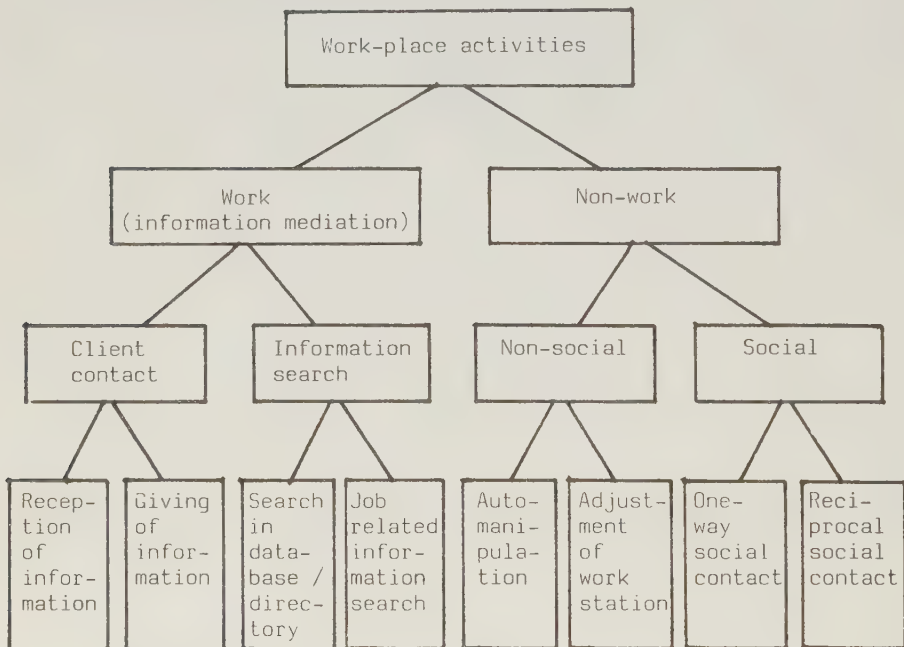


Fig. 1. A taxonomy of telecom operators' work behaviour. This structure is the basis for the categories used for coding the videofilmed operator behaviour in the study.

The meaning of the 10 categories, which constitute the key to the registration of the operator behaviour occurring in the films, is given in detail in Table 1.

Table 1. The meaning of the categories used for coding telecom operator work behaviour.

Code	Meaning
1	Reception of information from client. In both VDU and MAN, this may include simultaneous writing of relevant information (keyboard, paper and pencil), as well as listening to and waiting for answers.
2	Giving of information to client. Includes primarily talking, but also other simultaneous activity.
3	Search for information in database (VDU) or near-directory (MAN) - in both cases, "quick-reference" directories are included. The search is primarily coupled to client contact, but occurs also in other work.
4	Other job-related information search. Includes a) getting, perusing, and returning "far-directories", b) asking for and receiving information from another operator, c) writing down and reading information.
5	Auto-manipulation. Includes adjustment of own clothers or glasses, getting up and sitting down again, waiting for being connected, staring at an empty screen or at nothing.
6	Adjustment of work-station. Includes adjusting VDU, chair, Head-set, or microphone, tidying up between calls.
7	One-way social contact. Includes verbal and non-verbal attempts to establish social contact, or in general, such behaviour as may lead to social interaction.
8	Reciprocal social contact. Includes verbal and non-verbal interaction.
9	"Time out marker". Unspecified absence from the work-station and out of the picture.
0	"Switch down marker". Breaking of client connection.

Recording apparatus

A MICRONIC 445 portable data collection terminal was used to record the observation data from the videofilms. The use of this recording device in behavioural observation has been described by Briem (1983).

Procedure

The observation of the videofilms was done in a semi-darkened room, and the films were shown on an ordinary TV monitor screen. The timing and recording of behaviour was started at the beginning of each film. The observation

carried on for as long as the focal operator did not leave the picture permanently, or as long as the film lasted (max. 31 minutes). The six films containing single focal operator working at a VDU were observed only with respect to the behaviour of that operator, while for the seventh film showing a group of operators at work simultaneously in the MAN condition, the behaviour of a total of three operators was observed separately. At the end of each recording session, the data were transferred from the MICRONIC 445 terminal to a UNIVAC 1100/80 mainframe computer for subsequent analysis.

R e s u l t s

The first stage in the treatment of the data was an analysis in a series of computer programs written by the first author. The first version of this program package is described in Briem (1983). The programs are designed so as to allow the user to (1) edit and check the data successively, (2) transform the raw data to forms that may be treated more effectively in statistical analytic programs, and (3) get a clearer idea of the possible meaning of the data through a presentation of summary statistics, frequency distributions etc. Table 2 summarises the main results from the analysis of the observational data. The table shows the relative frequency of the 10 behaviour categories for all the operators - the measure used here for category 0 is rate of occurrence during the time of observation, while for the other 9 categories, percent occurrence gives a better picture. Due to the hierarchical nature of the taxonomy used, related categories may be combined in order to give a clearer picture of some of the more important relations in the data.

It was considered necessary to take particular care in the use of rigorous statistical analyses of the data at this stage owing to the small number of operators included in the study, as well as to the fact that in MAN, the behaviour of the operators is both non-independent and synchronous. However, a series of sequential analyses of the data was performed, revealing both expected and unexpected and interesting relationships. The results from these analyses are described in a companion paper to the present one (Briem, 1984).

Table 2. The relative work behaviour of the 9 telecom operators in the study. Behaviour 0 is represented by its rate of occurrence per minute, while behaviour categories 1-9 are represented by their percentage occurrence.

Operator	Behaviour category									
	0	1	2	3	4	5	6	7	8	9
1 (VDU)	0.33	17.52	12.31	11.29	25.20	3.73	0.86	1.48	6.82	18.48
2 (VDU)	0.93	15.53	24.24	15.55	5.89	25.65	2.04	2.94	3.42	1.89
3 (VDU)	0.78	16.34	15.13	10.27	0.00	33.37	11.37	3.27	5.97	2.54
4 (VDU)	1.08	16.14	12.85	15.02	0.82	46.01	0.00	3.10	3.54	0.64
5 (VDU)	1.38	20.37	17.53	24.58	0.81	30.24	0.06	0.60	3.16	0.00
6 (VDU)	0.93	18.98	25.54	19.94	1.46	30.39	1.46	0.00	0.00	0.00
7 (MAN)	0.58	13.11	10.24	27.77	8.00	26.42	6.87	1.51	3.14	0.00
8 (MAN)	0.39	9.50	8.34	22.24	11.88	19.08	7.06	8.10	10.70	1.98
9 (MAN)	0.42	15.37	6.55	42.28	5.55	14.46	5.56	1.73	5.52	1.79
$\bar{X}$ =	0.76	15.87	14.74	20.99	6.66	25.48	4.25	2.53	4.70	3.03
S.D. =	0.36	3.19	6.64	9.93	8.11	12.08	3.72	2.37	3.01	5.88

Discussion

The primary object of the present study was to explore the possible uses of behaviour observation as a tool for job analysis. In addition, it was intended to throw light on various aspects of the work behaviour of the telecom operators in this particular organisational environment. We believe that we were successful in both of these undertakings. As regards the first objective, no part of the study presented us with any particular obstacles, especially as many of the procedural tools of our previous behaviour observational studies could be brought to bear here. This applies especially to the data processing apparatus and computer programs, as well as to the creation of the taxonomy and other conceptual tools used.

The taxonomic categories chosen to represent the telecom operators' work behaviour served their intended purpose very well. There were seldom any doubts as to which category should be chosen for the observed behaviour, and the resulting registration sequences may be considered to be a fairly accurate description of this behaviour. The success of the coding system may be attributed partly to the highly structured nature of the operators' work, but we are inclined to consider it to be principally due to the nature of the taxonomy employed.

The taxonomy was kept somewhat coarse-grained in order to avoid confusion during the coding process. But, in case a finer-grained analysis of any aspect of the operators' behaviour was desired, there exists the possibility to expand the number of categories at the "leaves" of the binary tree until the necessary detail is obtained. Thus, our tree might be expanded on either or both sides, depending on whether one wanted a more detailed registration of either work or social behaviour, or an increase in the detail of the registration in general. The reason for the shape of our particular tree depends on our desire to keep the registration uncomplicated and requiring relatively few decisions, while at the same time covering the telecom situation as completely as possible.

Some interesting effects appear in the analyses of the data, especially with respect to the differences between the two work conditions, VDU and MAN. What first emerges is that the time spent in the activity registered as "client contact" (taxonomic categories 1 and 2) is somewhat greater in VDU than MAN, while the reverse is true of "information search" (categories 3 and 4). The amount of time spent in "work" (categories 1-4) is about equal for the two conditions, or approximately 60%. Yet, the rate of calls answered in VDU is about twice as high as in MAN. What these results seem to imply, then, is that telecom work in VDU is about twice as productive as work in MAN.

It was obvious from the results that the behaviour of individual operators in the telecom work situation differed considerably with respect to many of the behaviour categories used. However, the variations in actual work behaviour observed for the different operators was less than what we had anticipated. At the same time, the total duration of actual work behaviour, as defined here, is somewhat less than expected, considering the highly structured nature of this type of work. We had also expected the social interaction engaged in by the operators in the MAN condition to be considerably greater than that in the VDU. This turned out not to be the case, except for one of the three operators in the MAN condition. The time spent in social interaction and attempted social interaction by this operator (operator 8) far exceeded that of any other operator in the whole study, while, on the other hand, her work behaviour occupied, relatively, a normal length of time. Another operator who showed a work behaviour pattern which differed from that of the others was operator 1. This operator was somewhat older

than all the others in the study, and seemed to spend a lot of her time in a coordinating capacity. This is reflected in the inflated percentage values for categories 4 and 9. In general, the telecom operators observed here all exhibit individual work styles while performing their job according to the employer's specifications.

The sample of work sequences used in the study is too limited to base definite conclusions on regarding the relative proportions of activities of specific types occurring during the work periods. This applies particularly to the MAN condition, where all three observation sequences are based on the same work period. However, some highly interesting pointers to the relations existing among the various categories used to record the operators' work activities may be derived from the results. The most important of these have been discussed above, and they include 1) relative efficiency and productivity of work in the VDU and MAN job conditions, 2) job composition and relative work content in VDU and MAN, and 3) similarities and dissimilarities between individual workers doing the same job.

Furthermore, it may be concluded from the present study that behaviour observation is eminently suitable for job analysis. It combines a detailed sequential recording of task-related work behaviour with a possibility to study the non-work or social activities that the worker engages in in the job situation, and it may be used to expose the balance that exists between the two at the place of work. In addition, it offers the investigator the possibility to bring to bear a range of analytical techniques from simple descriptive statistics to time-series analysis of sequentially recorded behaviour. Thus, it makes possible a much fuller analysis of various complicated job situations than has hitherto been practicable.

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*Application of Behaviour Observation for Investigating
Relative Work Content, Behavioural Style, and
Social Interaction in Telecom Work*

2. Sequential dependencies

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A b s t r a c t. - Examined the work-place behaviour of 9 telecom operators, as represented by the categories of a taxonomy previously defined for this purpose. Descriptive statistics were obtained for the data, and event- and time-sequential relationships were extracted with lag sequential analyses. The results indicate that, while the telecom work-place behaviour is to a considerable extent defined by the information work done, there exist also quite strong individual components in the behavioural sequences of the operators. These results are discussed in the light of some organizational and social aspects of modern information work, and the use of sequential analyses in the study of these factors is evaluated.

I n t r o d u c t i o n

In a previous paper in this series (Briem & Nyström, 1984), the idea of using behaviour observation to investigate the work-place behaviour of telecom operators was introduced, and it was concluded that behaviour observation was a proper method to use in this context. The types of activity that a telecom operator might engage in when at the place of work were assigned to various classes which were then combined in a taxonomy suitable for behaviour registration. The results from the first analyses of the data collected in the study were found to clarify the issue of the static composition of the behaviour observed.

The right classification of the behaviour under observation in a given study is prerequisite for acceptable validity and reliability of the results. Thus, one must know that what is being recorded is a) of relevance to the aim of the study, b) what one intends to record, and c) what another trained observer would record in the same circumstances, or one would record oneself if the observation was repeated. Simplicity, structure, and lack of ambiguity are all the hallmarks of a good system. These issues are discussed at some length by Hollenbeck (1978). One might even say that the final conclusion in a study can never be better than the quality of the data collected. There-

fore, considerable time and care was spent on the construction of the present a priori taxonomy.

In the present paper, the results from a series of sequential analyses and related manipulations of the observed telecom operator data are reported. The methods used have mostly been developed within ethology, but have also been applied to psychological research problems with increasing frequency lately. A time series model approach to behaviour analysis in human factor research has been advocated by other investigators (e.g. Carter, 1984), but previous studies have mostly been designed to throw light on behaviour extending over longer time periods and at coarser levels of classification than what is done here. However, a micro-analytic approach in behaviour observation is by now fairly well established in other branches of psychology, such as comparative (e.g. Sachett, 1978), developmental (e.g. Bakeman & Brown, 1977), educational, (Kratochwill, 1977), and clinical psychology (Kratochwill & Piersel, 1983). The idea of using techniques involving the analysis of the complex interrelationships in social and other interactive behaviour observed in organizational settings has been advanced previously (Cook & Campbell, 1976), but reports of studies involving these techniques have been conspicuously lacking in the literature. Until recently, the most closely related approach in industrial and organizational psychology has been the work study methods that originated with Taylor (1911) and Gilbreth (1919) and job analysis methods that derive from this tradition. But these approaches are limited to the analysis of skills performed within and as a part of a total work situation, and are less concerned with the global, sequential dependencies between the actions of the workers at the place of work. Hence, there is a fundamental difference between the two approaches, sequential analysis of work behaviour, on the one hand, and time and motion study, on the other, a difference exhibited less in the methods used for data collection than the intention of the studies and the use of the results. A review of several other methods used in the direct observation of work behaviour is presented by Smith (1976).

It is apparent that the construction of a repertoire of methods for behavioural investigation in this area of psychology is not particularly far advanced, and that much work still needs to be done before this edifice rests on secure, empirical foundations. Hence, it is to methodological issues that the present report will primarily be devoted. The principal hypothesis

put forward here is that a worker's performance at a given job cannot be evaluated in isolation from the total work situation at the time, and that this situation includes not only the task itself and the physical amenities available for carrying it out, but also the social interaction with fellow workers and management. The fuller the information that is available about the work situation in which the evaluation takes place, the better the chance of predicting the future performance of the worker. Relevant information about the performance of the worker at his task may be obtained by productivity measures or time and motion study, and social aspects of the work situation may be investigated through the use of questionnaires or interviews. These methods of obtaining data may yield much worthwhile information about various aspects of the work done, and this may prove invaluable for showing what or how a worker does or what a worker thinks in connection with a certain task. But these measures cannot, by themselves, provide an integrated picture of the composition of the worker's actual behaviour in a given work situation at any given time. Thus, in order to gain a sound idea of the function of a particular act or action within the stream of behaviour of a skilled worker at his job, it is necessary to examine how the behaviour in question fits in with the sum total of other behaviour of the worker at his place of work.

The analyses and arguments presented here are a direct continuation and extension of the work reported in a previous paper (Briem & Nyström, 1984). The main objective here is to find and display behaviour patterns which are stable for the group being investigated, as well as patterns which are stable for the individual members of the group. These patterns may not always coincide. We shall also examine how variations in the details of task content affect the operators, insofar as this is reflected in their behaviour patterns. The study is, thus, rather intended to serve as a practical example of how sequential behaviour analyses may be used in this applied area of psychology than to be definitive of telecom work behaviour. In particular, the study is intended to show how the behaviour of skilled operators may be analysed and separated into its constituent parts, and then reassembled in such a way as to display the internal relations in the observed behavioural streams. The aim of the discussion that follows is to clarify further the possible application of these techniques in organizational psychological studies and the use to which they may be put in investigations of work in modern office environments.

Method

The work place behaviour of 9 telecom operators was videofilmed and coded according to an a priori taxonomy. Details of the apparatus used, filming, behaviour registration, and taxonomy have been reported in a previous paper (Briem & Nyström, 1984). All 9 operators did the same kind of telecom work in name and number information retrieval service in response to client requests. Six of the operators, referred to here as 01-06, worked in a data-based condition at VDU work stations, while the other three operators, referred to as 07-09, did conventional telecom work, using hard-copy directories and accessing the information manually. These two work conditions are referred to as VDU and MAN, respectively. For details of the telecom work and physical conditions of the operators, cf. Hedman & Briem (1984).

The initial behavioural taxonomy used contained 10 mutually exclusive and exhaustive categories of telecom operator behaviour, grouped as 4 work categories, 4 non-work categories, and two 'marker' categories. These categories were referred to, respectively, by the numbers 0-9. However, because of the different requirements of the analyses done of the data in this part of the study, the grouping of the categories has been rearranged, so that, here, category '0' is grouped together with categories '1' and '2' at the second level of the hierarchy, and category '9' with categories '5' and '6'. Also, the categories at the different levels have been given 4-letter acronymic names reflecting their respective definitions. The resulting arrangement, which is shown in Table 1, is no longer a binary tree. However, this is of no great practical importance in the present context.

Table 1. The behavioural taxonomy used. Categories at the 3 hierarchical levels are labeled with acronyms designating their contents. A short description of each category is included, together with numbers which are the previous designations (Briem & Nyström, 1984).

Work place behaviour				
Level:	1	2	3	
WORK	CUST	RECV	(1: gets request from customer)	
		GIVE	(2: gives answer to customer)	
		SWID	(0: breaks customer contact)	
	INFO	DBAS	(3: searches in database)	
NOWK	SOLO	ISCH	(4: searches for information)	
		AUTO	(5: automanipulation)	
		ADJT	(6: adjusts work station)	
	COMM	TOUT	(9: time-out of observation)	
		ONEW	(7: one-way communication)	
		TWOW	(8: two-way communication)	

The hierarchical nature of the taxonomy makes it possible to combine categories at lower levels to form categories at higher levels, when necessary. This is important when the analysis of grosser units is required, as is sometimes advantageous in order to illustrate more general trends. This method is employed here in some of the analyses of the data.

Apart from this the set-up was the same as that described in the first report in this series, to which the interested reader should refer. The statistical analyses and data-manipulations are described in the following section.

One aspect of the method of data collection that somewhat hampered the original registration was the unavailability of the auditory channel from the customer to the operator. This made the start of the communication with the customer somewhat difficult to detect in some cases, and meant that the observer had to infer from the operator's behaviour when the customer was talking to her. However, the observers were able to achieve an acceptable level of agreement on this category, but much of the remaining disagreement in the registration was due to the scoring of DBAS by one observer and RECV by the other, and vice versa (as may be read from the inter-observer agreement measures presented below, and the difference in the Kappa and Ap statistics).

R e s u l t s

A preliminary analysis of the data, giving summary statistics of work place behaviour of the telecom operators, was reported by Briem and Nyström (1984). A summary of these results is given in Table 2. The reliability of the coding system was assessed by comparing the representations of two different observers of one of the behaviour sequences used here (operator 05). First, two different representations of the sequence by one observer were compared to the one representation by the other observer, and then the two representations by the first observer were compared to each other. The agreement was measured with the Kappa statistic (Cohen, 1960), and was found to be 0.31 and 0.31 (max kappa = .87 and .86), respectively, ($p < 0.01$) for the two comparisons of the first to the second observer, and 0.65 ($p < 0.01$) for the comparison of the first observer to himself (max kappa = .95), which indicates acceptable reliability levels. The Ap statistic (Light, 1971) was in all cases very large ($p < 0.01$), indicating a consistent overlapping of categories (cf. above). A program developed by Antonak (1977) was used to calculate these statistics. After completion of the analyses, the data were transformed into event-base and time-base sequences of codes representing the observed behaviour (cf. Bakeman & Dabbs, 1976), where the time-base code sequences represent behaviour occurring at one-second inter-

vals. The event- and time-base sequential data were analyzed with Roger Bakeman's ELAG program (Bakeman, 1983) which makes use of Gene Sackett's lag sequential analysis method (Sackett et al., 1979) to calculate the dependencies between categories of behavioural events in sequences of coded data.

Table 2. Average work behaviour (10 categories) on several descriptive statistics for the 9 operators. D = duration of behaviour in seconds, N = number of occurrences of a behaviour category, E = behaviour element.

Category:	RECV	GIVE	DBAS	ISCH	SWID	AUTO	ADJT	ONEW	TWOW	TOUT
D	272.9	253.9	350.8	120.6	35.9	425.9	60.9	39.3	78.6	52.8
N	95.7	115.4	44.1	8.3	21.6	29.4	6.9	10.4	8.0	1.4
Mean D/E	3.1	2.2	10.2	10.5	1.9	13.2	7.1	3.4	9.2	17.8
SD D/E	3.7	1.6	9.6	13.2	1.1	13.5	5.5	2.9	7.3	7.7
% D	15.9	14.7	21.0	6.7	2.1	25.5	3.9	2.5	4.7	3.0
% N	27.4	32.5	12.9	2.7	6.1	9.0	2.7	3.5	2.7	0.5
Rate E/min.	3.3	4.1	1.8	0.4	0.8	1.1	0.3	0.4	0.3	0.1

It was described above how 10 different categories of events were used to represent the observed behaviour of the telecom operators. In order to get a comprehensive picture of the sequential relationships between these behavioural events, all 10 categories were in turn used as criteria (C), relative to which the conditional probabilities of other behavioural events (E) were calculated at various lags. The conditional probabilities are noted here as 'P(E/C)', which should be read as 'the probability of E given C'. (For a more detailed description of these relationships and related statistics, cf. Bakeman, 1983; Chatfield & Lemon, 1970; Gottman & Bakeman, 1979; Miller & Frick, 1949). For the event-base sequences, lags from -1 to 18 were used, and for the time-based sequences, lags from -1 to 36 were used. The calculations were done for each of the 9 operators individually, as well as for the pooled data from a) all 9 operators, b) the 6 operators working in the VDU condition, and c) the 3 operators working in the MAN condition.

Event-base probability profiles. Because of the vast amount of probability data generated in the lag sequential analyses, it is difficult to get a clear view of the relations contained in the results. One way of reducing the data to manageable proportions is to construct probability profiles of the results (cf. Bakeman & Dabbs, 1976). This was done here. The profiles for lags 1 to 9 for the event-base sequences for individual operators, together with the pooled profile for all 9 operators, are shown in Figure 1 (Note 1). Profiles for the different P(E/C) combinations are grouped together, 10 at a time, according to criterion. In each P/E/C plot, the ordinate gives the conditional probability value from 0.0 to 1.0, and the abscissa the lags from criterion from 1 to 9. The numbers assigned to the operators, i.e. 1 to 9, are plotted at each of the 9 lags, and the probability values for the different operators can be read off the ordinate. The pooled probability profile for all 9 operators is given as an unbroken line in the plot, and the baseline denoting the simple (expected) probability for the group is shown as a broken line parallel to the abscissa. The values in the plot which have a statistically significant z score associated with them are surrounded by a ring. It is worth noting that an event-base sequence is so defined that a behaviour category code cannot follow itself at lag 1. This has two important consequences: a) The probability of a category at lag 1 is equal to zero when it is itself the criterion, and b) the simple probability (baseline) is higher at lag 1 than at other lags. The latter is taken into account here in the calculation of conditional probabilities, but is not shown in the profile plots. The probability profiles were laid up and plotted in a series of computer programs devised by the present author.

The z scores relative to the conditional probability values were calculated according to the formula proposed by Sackett (cf. Bakeman, 1983). A conditional probability value was taken to be significantly different from chance if the z score associated with it fell beyond the 5% limits of probability. However, when it was a matter of deciding the significance of the pooled data, i.e. the group profile, it was considered more appropriate to use the sign test (Siegel, 1956) to assess the probability of the observed split in the number of operators whose z scores differed from the expected value (cf. Bakeman & Brownlee, 1980). The statistically significant relations between behaviour categories for lags 1 to 18 is shown in Table 3. Thus, Table 3 a, lags 1 to 9, refers to the significant relations for the whole

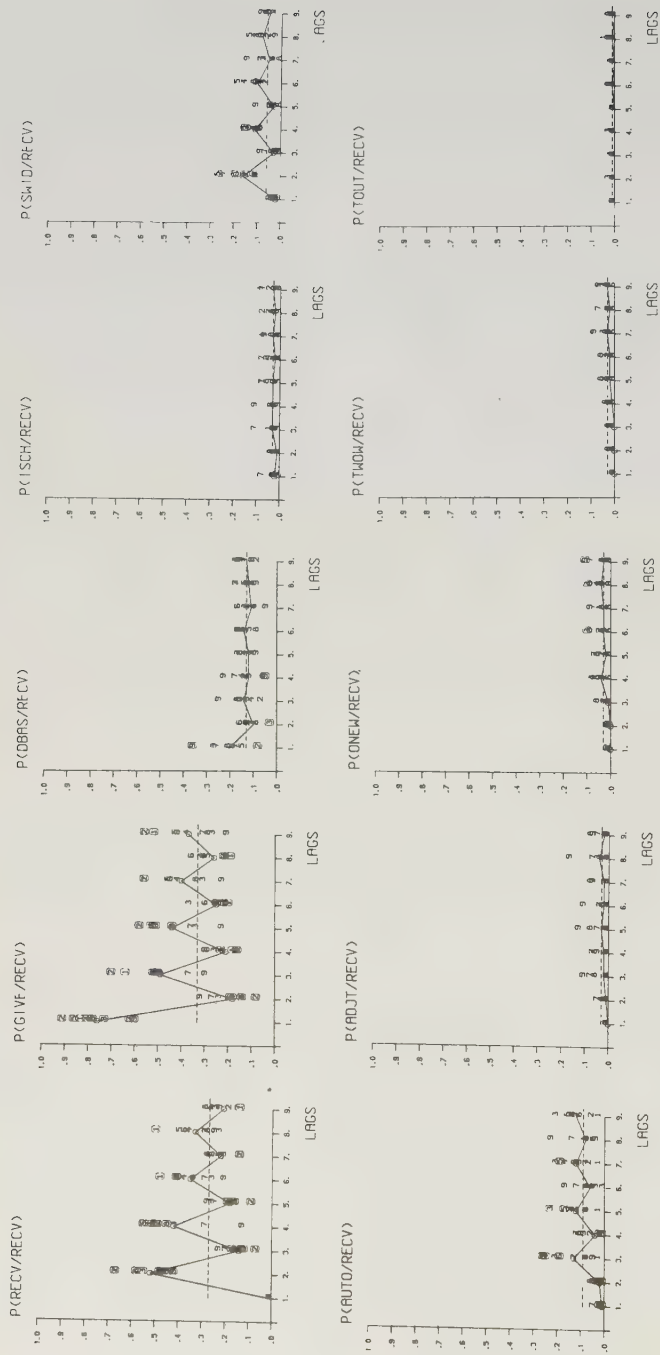


Fig. 1. Event-base probability profiles for the 10 behaviour categories with RECV as the criterion category, lags 1-9. The probability values for individual operators are shown as the operator number, the group profile as an unbroken line, and the expected probability as a broken line.

group shown in Figure 1, i.e. when RECV is criterion, Table 3 b, refers to the case when GIVE is criterion, and so on. The significance as given by the sign test often, but by no means always, coincides with the z scores for the pooled data - the lack of coincidence usually being due to a significant z score resulting from the disproportionate contribution of a few operators.

Table 3. The statistically significant (5% level) 'follows' relations at lags 1-18 for the pooled event-base data. Significant positive relations are shown as '+', and significant negative relations as '-'.

	a)	b)	c)	d)	e)
	CRITERION = RECV	CRITERION = GIVE	CRITERION = DBAS	CRITERION = ISCH	CRITERION = SWID
Lags:	123456789012345678	123456789012345678	123456789012345678	123456789012345678	123456789012345678
Category					
RECV	/+--+ -+-	+--+--+ -+	-+--+ +- + -	- - +	- - -
GIVE	+--+--+ -	/+--+++	+--+--+ -+-	- - -	- - +
DBAS		++ -+	/+	+ -	-
ISCH	-	-	- - -+	/	- - - -
SWID	-+--+ +	+--+ - -	- - + -	- -	/- - -
AUTO	- - +	- -	- - -	+ -	+ - - -
ADJT	- -	- - +	- -	- -	- - - -
ONEW	- - -	- - - +	- - - -	-	+ + - +
TWOW	- - - -	- - - -	- - - -	- - - -	- + - -
TOUT	- -	- -	- - - -	- - - - -	- - - - -

	f)	g)	h)	i)	j)
	CRITERION = AUTO	CRITERION = ADJT	CRITERION = ONEW	CRITERION = TWOW	CRITERION = TOUT
Lags:	123456789012345678	123456789012345678	123456789012345678	123456789012345678	123456789012345678
Category					
RECV	- - +	- -	-		
GIVE	- - -	- -	- -	- - -	
DBAS	+ -	- - -	-	- -	
ISCH	- -	- - -	-		+
SWID	- - - +	- - - - -	- - -	- - -	
AUTO	/ - -	- - - - -	+ + - - -	+ - -	
ADJT	- - - - -	/ - - - - -	- - -	-	
ONEW	+ + + -	- - -	/+ - - - -	+ - - - -	
TWOW	+ + + - -	- - -	+ + - - - -	/+ - - - - -	
TOUT	- - - - -	- - - - -	- - -	+ - - - - -	/

There exist two different types of relation, 'positive' and 'negative', between a criterion and a related event. The positive relations indicate that if a certain behaviour does occur, some other behaviour or sequence of behavioural elements is likely to occur before or after the given behaviour, either immediately or after some specific number of intervening behavioural occurrences. The negative relations indicate that a certain behaviour or a sequence of behavioural elements is likely not to occur at some specified position in the behavioural sequence, given the occurrence of the criterion behaviour (Note 2). Thus, Table 3 a shows that given RECV, RECV is highly likely to occur at lags 2, 4, and 8, GIVE at lags 1, 3, and 5, and SWID at lags 2, 4, and 6. But also, given RECV, RECV is highly unlikely to occur at lags 3, 5, 7, and 9, GIVE at lags 2, 4, 6, and 8, ISCH at lag 1, SWID at lags 1, 3 and 5, AUTO at lags 1, 2, and 4, ADJT at lags 1 and 2, ONEW at lags 1, 2, and 3, and TWOW at lags 1, 2, 3, 4, and 6. And similarly for Tables 3 b-j.

Examination of Figure 1 and Table 3 enables one to discern groups of positive and negative relations between the behaviour categories. There appear to be two major groups of categories in the data. The first of these groups, the 'work group', is comprised of RECV, GIVE, and DBAS, and the second group, the 'non-work group', of AUTO, ONEW, and TWOW. The category SWID appears as a link between the two groups. Some of the relations between categories seem to be cyclic in character. Thus, RECV, GIVE, and DBAS have alternately positive and negative relations to RECV and GIVE, as have RECV and GIVE to SWID, SWID to AUTO, ONEW, and TWOW, and these last three to each other.

There also appears to be a tendency, at least at the early lags, for criteria from the first group to have positive relations to events in that group, but negative relations to events in the second group, and vice versa for criteria from the second group. Thus, there is a tendency for work items to be positively related to work items, and non-work items in the operators' behavioural sequences. The negative relations are somewhat more numerous than the positive ones in all categories, except for TOUT which does not have any significant relations to the other categories.

In addition to these two types of relation, there can be said to be a third type of relation between behaviour categories, viz. a relation that is

neither very likely or unlikely, a 'may-occur' relation between behaviour categories. Thus, the absence of statistically significant relations between behaviour categories in the grouped data does not mean that the relations do not exist. What it does mean is that the behaviour does not occur in relation to any of the other behaviour categories with any marked regularity. Also, the behaviour may occur with regularity in the repertoire of some of the operators, but may be absent from the repertoire of others. We shall see some examples of this below. Statistically, the may-occur relations should occur far more often than the positive and negative relations between categories in the data, whose probability is, by definition, less than 5%.

Event-state diagrams (Note 3). In order to clarify matters further, state diagrams showing the event sequential relations between the different categories were constructed. The relations shown in these diagrams are 'follows' and 'precedes', and for the sake of clarity, only the statistically significant probabilities of one event either immediately following (at lag 1) or being immediately preceded (at lag -1) by another event are given here. The event categories are represented as boxes containing the category names. The relations between events are given by unbroken and broken arrows which connect the boxes. Thus, referring to the two related event categories as A and B, 'A $\longrightarrow$ B' indicates that B tends to follow A, and 'A $\longrightarrow$ B' indicates that A tends to precede B. The probability of the 'B follows A' relation is shown next to the line without parentheses, and the probability of the 'A precedes B' inside parentheses. When both relations are significant, only an unbroken line is shown with two probability values. The state diagrams are shown in Figures 2 and 3. Figure 2 a shows the pooled data for all operators, Figure 2 b the pooled data for operators 1-6 (VDU), and Figure 2 c the pooled data for operators 7-9 (MAN). Figures 3 a and 3 b give the individual results for two of the 9 operators. The response patterns of these two operators (06 and 08) illustrate how the operators may differ in this respect (cf. below). The significance of the pooled and individual data was determined as before, with the allowance in Figure 2 c that the trend was counted as 'significant' if the z scores for all three operators differed significantly in the same direction from the expected value.

Fig. 2 a

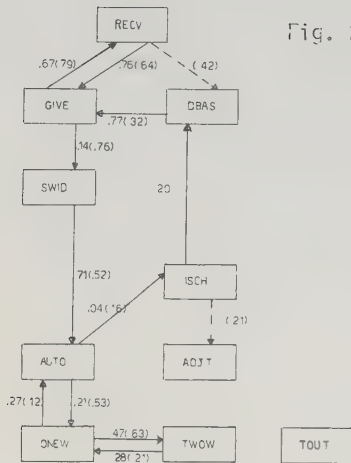


Fig. 2 b

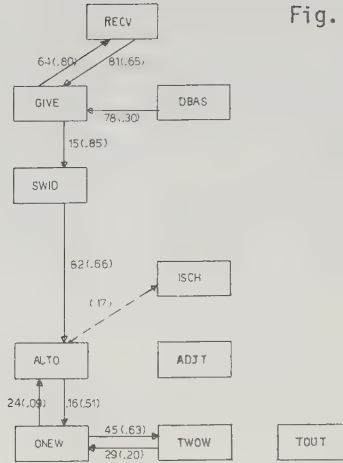


Fig. 2 c

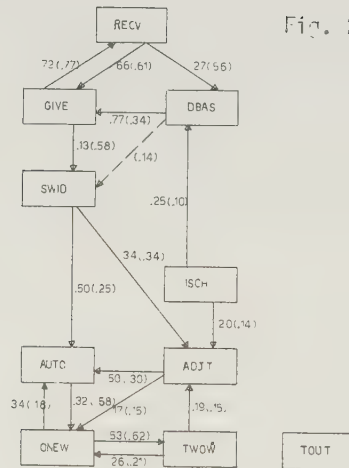


Fig. 2. Event-state diagrams for the pooled data, showing the relations 'follows at lag 1' and 'precedes at lag -1'. 2 a: Pooled data for operators 1-9. 2 b: Pooled data for operators 1-6. 2 c: Pooled data for operators 7-9.

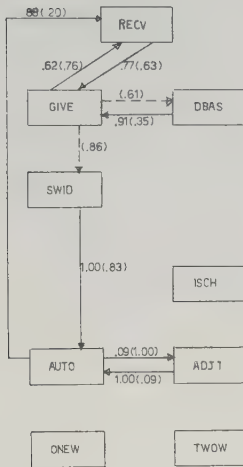


Fig. 3 a

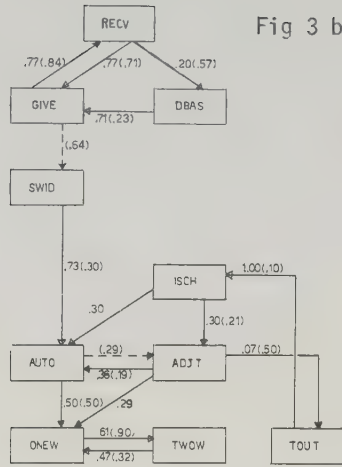


Fig 3 b

Fig. 3. Event-state diagrams for two of the 9 operators observed in the relations 'follows at lag' and 'precedes at lag -1'. 3 a: Operator 06. 3 b: Operator 08.

The grouping of the elements in the diagrams is the result of the preliminary analysis of the probability profiles, and shows a rough similarity to the a priori taxonomy. However, the category SWID, which is the WORK behaviour delimiter, has gained a more central position, and ISCH has been moved closer to the NOWK categories, as elements from this category apparently occur in both superordinate categories. Elements from the category RECV are logically the first to occur in every sequence of work behaviour involving directory enquiries, and this category is, therefore, placed at the top of the diagram.

As an example of how we can use these diagrams to describe the behaviour of the operators, we shall now look at Figure 3 a (operator 06), as it contains the simplest relations observed in the study. We begin with the category RECV, which is significantly followed only by GIVE ($p = .77$).

GIVE is most typically followed by RECV ($p = .63$), but also by DBAS ($p = .35$), and these two behaviour categories comprise together almost all the preceding conditions for GIVE ($.63 + .35 = .98$). RECV is nearly exhaustively preceded by the categories GIVE ($p = .76$) and AUTO ($p = .20$), and DBAS is nearly always followed by GIVE ($p = .91$). The work sequence is usually terminated by SWID which is mostly preceded by GIVE ($p = .86$). Thus, the occurrence of these four WORK categories, RECV, GIVE, DBAS, and SWID, can be described almost completely in terms of the other three, and only once do we need to invoke the occurrence of a NOWK category (AUTO), AUTO always follows SWID ($p = 1.00$), and is also nearly always preceded by SWID ($p = .83$), but sometimes by ADJT ($p = .09$). In its turn, ADJT is always preceded and followed by AUTO ($p = 1.00$). The only categories which significantly follow AUTO are ADJT ($p = .09$) and RECV ($p = .88$).

It is clear that the pattern of behaviour of operator 06, as exemplified in the observed film, may be accounted for fairly exhaustively by the occurrence of elements from 6 of the 10 behaviour categories that compose the taxonomy used here. These categories are RECV, GIVE, DBAS, SWID, AUTO, and ADJT. It may be seen that this operator did not leave her VDU work-station during the time that the video-recording was going on, as is shown by the absence of the categories ISCH and TOUT, and the fact that ONEW and TWOW are not present shows that she did not engage in communication with others during this time nor even try to do so. The picture that we get of operator 06 is that of a quiet, conscientious, and hard-working telecom operator. However, the work-place behaviour of this operator is not entirely typical of the other operators' behaviour (cf. Figures 2 and 3).

The flow diagram representation of the average behaviour of the operators is shown in Figure 2 a. We can see immediately that the two relations 'follows' and 'is preceded by' tend both to apply in most cases where a relation exists between any two behaviour categories. Exceptions are RECV-DBAS, ISCH-DBAS, and ISCH-ADJT, for which only one of the relations is significant. However, the probability values associated with the two relations may be considerably different. This is in many cases the result of a difference in the frequencies of occurrence of the different categories. Imagine a category (A) of which there are many behavioural instances, where the events may precede several different categories (B) about equally often, and where none of the associated 'B follows A' relations are statistically significant. But for

one of the B categories, all of the preceding events are in category A, and for this category the 'A precedes B' relation is statistically significant. Thus, GIVE precedes DBAS with a probability of .45 in the pooled data, and RECV precedes DBAS with a probability of .42. This relation is statistically significant at the 5% level only for RECV-DBAS, but not for GIVE-DBAS. This is usually the reason for the apparent discrepancy in the relations seen in the diagrams for the individual operators (cf. Figure 3). Thus, high conditional probabilities coupled with non-significant relations may in most cases be traced back to the simple probabilities of the events involved, and similarly for low probabilities with significant relations. Another reason for a high conditional probability and a non-significant relation, this time in the pooled data, is that a certain relation may be true for only a few operators and not for others, and those few operators contribute disproportionately to the total conditional probability. This is the case for the relation 'ISCH follows TOUT' where the pooled conditional probability equals .33, but the relation is not significant since most of the instances of TOUT are contributed by only three operators.

Time-base relations. So far we have only considered sequential relations between categories without regard to the time taken by the occurrence of behavioural events. However, in order to obtain a more comprehensive view of the telecom operators' behaviour, temporal relations must also be taken into account. As was mentioned above, the time-base data consist of sequences of codes representing the occurrences of the different behavioural categories at one-second intervals. Whereas in the event-base sequences, codes were not allowed to follow themselves, and each new occurrence of a behavioural code signified the transition into a new state, in the time-base data sequences, the same code may follow itself, indicating a continuation of the current behavioural event. The number of successive codes then denotes the length of the behaviour in seconds (Note 4).

Time-base probability profiles. The probability profiles for the time-base data for lags 3 to 27 stepped by 3 are shown in Figure 4. (cf. Note 1.) The difference between these profiles and the previous ones for the event-base data are at once apparent. Here, the shape of the profiles is less jagged, due to the fact a) that the behaviour elements are extended in time and

b) that their length is highly variable (cf. below). The profiles for behaviour elements that are lagged from their own occurrence tend to begin at a high probability level which gradually decreases, while the profiles for other element combinations may begin at a low probability value and increase to a higher one or vice versa. Table 4 gives the statistically significant 'follows' relations at lags 2 to 36 stepped by 2, where each lag represents one second in real time, for all categories given each of the categories in turn as criterion. The relations are for the pooled data, and all category combinations are represented. As previously, there are two main, functional category groupings. Thus, RECV and GIVE tend to follow themselves and each other, and SWID to follow both up to about lag 20, while GIVE, DBAS, and SWID tend to follow DBAS. Actually, all categories tend to follow themselves at the early lags, except for SWID. The categories that follow SWID are AUTO, ONEW, and TWOW. ONEW and TWOW tend to follow each other as well as themselves.

Table 4. The statistically significant (5% level) 'follows' relations at lags 2-36, stepped by 2, for the pooled time-base data. Significant positive relations are shown as '+', and significant negative relations as '-'.

	a)	b)	c)	d)	e)
	CRITERION = RECV	CRITERION = GIVE	CRITERION = DBAS	CRITERION = ISCH	CRITERION = SWID
Lags:	246802468024680246	246802468024680246	246802468024680246	246802468024680246	246802468024680246
Category					
RECV	+++++++ +	++++	--	-----	-
GIVE	+++++	+++++	+++++	---	-----
DBAS	- +	- ++	+++++	-----	-----
ISCH	--	--	++++	++++	- - -
SWID	++ ++	+++++	- ++	- - -	- - -
AUTO	-----	-----	-----	---	+++++++ ++ +
ADJT	-----	-	-----	---	-
ONEW	-----	---	-----	--	++
TWOW	-----	-----	-----	---	- + +++
TOUT	--	-----	-----	-----	
	f)	g)	h)	i)	j)
	CRITERION = AUTO	CRITERION = ADJT	CRITERION = ONEW	CRITERION = TWOW	CRITERION = TOUT
Lags:	246802468024680246	246802468024680246	246802468024680246	246802468024680246	246802468024680246
Category					
RECV	---	---	---	-- +	-----
GIVE	-----	---	- - -	---	-----
DBAS	-	-----	-	---	-----
ISCH	-----			-	-----
SWID	-----	-	-----	-----	-
AUTO	+++++++		---	-----	-----
ADJT	- - -	+++++	--	-	-
ONEW	--		+++++	+++++ ++	- - - - -
TWOW	-		+++++++	+++++++	---
TOUT	-	-	- -	-	++++ +++++

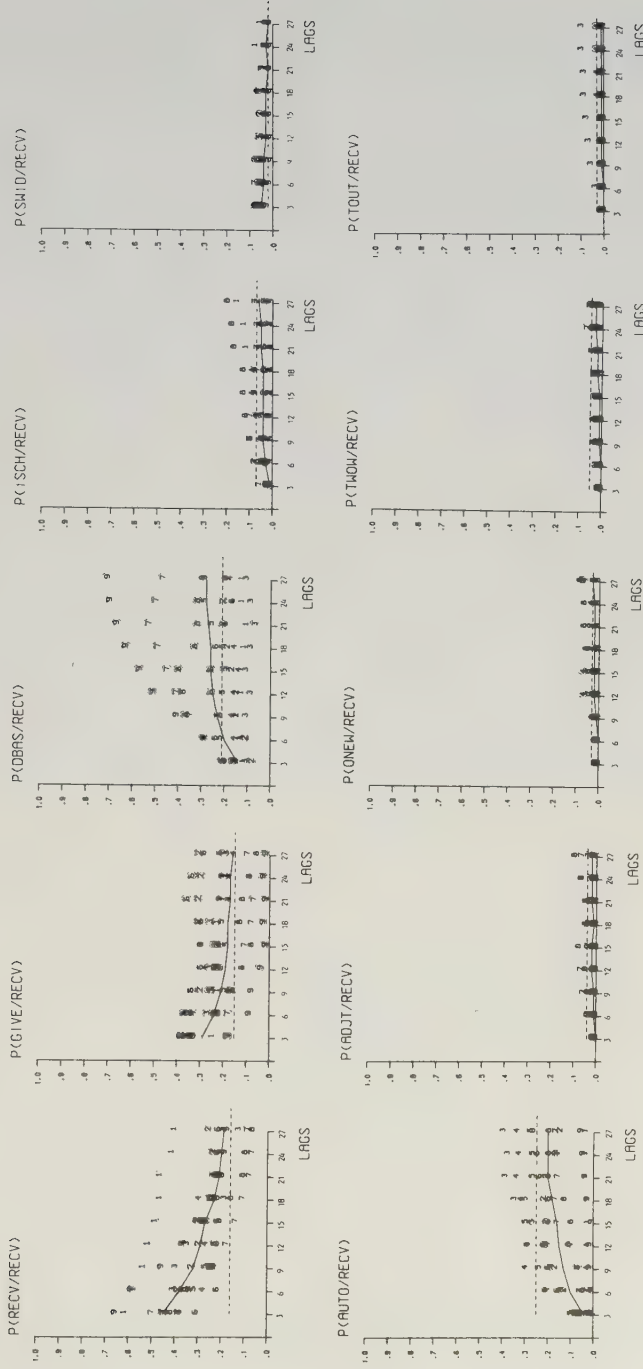


Fig. 4. Time-base probability profiles for the 10 behaviour categories with RECV as the criterion category, lags 3-27, stepped by 3. The probability values for individual operators are shown as the operator number, the group profile as an unbroken line, and the expected probability as a broken line.

State diagrams. A usual way of presenting time-base data is in a state diagram (cf. Note 3), where the primary objective is to show the exact probabilities of the transition between behavioural states. The full exposition of the probabilistic relations in a state diagram with N nodes requires that $N*N$ probability paths be traced between the nodes, which in the present case equals 100 paths for all 10 behavioural categories. As this would be too cumbersome, the 10 basic categories were combined at the second taxonomic level. The conditional probabilities for the 'following' relations (cf. above) between the 4 resultant categories are shown in Figure 5. It may be seen from this diagram that the probability of remaining in the same state is very much higher than that of transiting from one state to another. In view of the information shown in Tables 1 and 4 and Figure 4, this is not entirely surprising, as most categories do extend more than one second in time. The probability of transitions between certain states is considerably different from that between others. Thus, for example, while it is highly likely that an ongoing customer contact (CUST) will continue for a number of time intervals, it is more likely that a change from that state will result in a transition to information search (INFO) - i.e. the other WORK category - than to either of the NOWK categories. A similar pattern exists for INFO. A parallel trend may be observed for the categories SOLO and INFO. Furthermore, the probability of transiting between SOLO and CUST is higher than that of transiting between SOLO and INFO, CUST and COMM, or INFO and COMM.

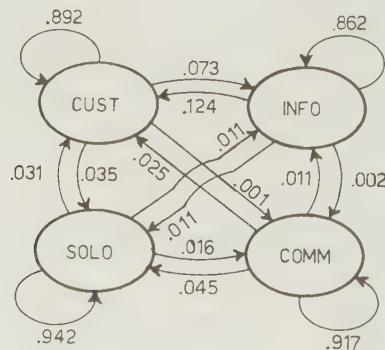


Fig. 5. State diagrams for the pooled data, in which the behaviour categories have been combined at the second taxonomic level. The diagram shows the relation 'follows at lag 1' for all possible (16) probability paths between the 4 categories.

Another aspect of the results which needs further consideration is the question why significant relations between categories occur at particular lags (cf. Tables 3 and 4). We have already deduced that certain categories produce functional groups, and that the main groupings in the present data are within the WORK and NOWK divisions of the taxonomy, respectively. This deduction is further supported by the results illustrated in Figure 5. The work-sequence is the one that is easier to define, and we shall now look at it further. Previously, a telecom work-sequence was defined as the expediting of a customer enquiry, or in behavioural terms, a sequence of behavioural elements beginning with RECV and normally ending with SWID (Note 5). A typical (hypothetical) work-place behaviour sequence for a telecom operator is shown in Table 5. The work-sequence shown here is 17 elements long, and the nonwork-sequence, intervening between the first and the next work-sequence, is 9 elements long. It was felt that knowing the length of these sequences would help explain some of the sequential dependencies that we have observed so far. Going back to the original data, the length of the work-sequences was determined, both the number of elements composing them as well as the time they took. The results are shown in Figures 6 and 7. Figure 6 shows the cumulative number of sequences of a certain length, extending into successive 5-element intervals. The total number of work-sequences expedited by the 9 operators was 164 during the time of observation. It may be seen that most of the sequences on which the conditional probabilities are based are less than 20 elements long, and more than half are less than 10 elements long. Hence, most of the significant conditional probabilities are based on short and frequent sequences. Similarly, more than half the sequences shown in Figure 7 from which the time-base conditional probabilities are derived are less than 30 seconds long. In other words, the very nature of the data make it more likely that significant transitional relations between behaviour categories will be obtained for short than for long lags.

The length of continuous contacts between the operators and customers was highly variable, measured both in terms of the number of behavioural elements and the time from first contact to the switching down. On the first measure the range was from 3 to 63 elements, with a median of 9.8 and an interquartile range of 10 (mean = 12.96, std.dev. = 10.56), while on the second measure the range was from 5 to 212 seconds, with a median of 30.0 and an interquartile range of 29 (mean = 45.60, std.dev. = 44.86). Despite

Table 5. A typical telecom operator work-place behaviour sequence.

```

RECV ..... "What number has NN in Notown?"
GIVE ..... "NN ...."
DBAS ..... searches
GIVE ..... "Just a minute!"
DBAS ..... continues searching
GIVE ..... "There are two people in Notown with that name."
RECV ..... "He's a plumber."
GIVE ..... "Do you know his address?"
RECV ..... "He lives either in P-street or Q-street."
GIVE ..... "Could it be P-street number 10?"
RECV ..... "Yes that would be it."
GIVE ..... "The number is xxx-xxxxxx."
RECV ..... "xxx-xxxxxx?"
GIVE ..... "That's right."
RECV ..... "Thankyou."
GIVE ..... "Good bye."
SWID ..... breaks connection
AUTO ..... strokes her hair
ONEW ..... looks intently at the operator sitting next to her,
              but does not catch her attention
AUTO ..... looks away and fiddles with her necklace
ONEW ..... looks at the operator sitting on the other side of her,
              catches her eye
TWOW ..... smiles and talks with the other operator
TOUT ..... stands up and walks away, out of the picture (toilet?)
ISCH ..... comes back and starts looking in a catalog
ADJT ..... sits down, adjusts her chair, puts on her glasses, logs in
ONEW ..... tries to catch the attention of another operator
RECV ..... signal light comes on, receives another enquiry

```

the smallness of the present sample, a comparison was made between the length of the sequences observed for the operators working in the two task conditions. The number of enquiries expedited was 129 by the operators in the VDU condition and 39 by the operators in the MAN condition. For the event-base sequences, the mean sequence length was 12.99 elements in VDU and 12.86 elements in MAN ($t = 0.09$, n.s.). For the time-base sequences, the mean length of the work-sequence was 36.01 seconds in VDU, but 77.31 in MAN ($t = 5.24$, $p < 0.001$). Even if these results can hardly form the basis of any wide generalizations because of the lack of independence in the data, they suffice to throw light on some of the differences between the groups which have been observed in the other analyses.

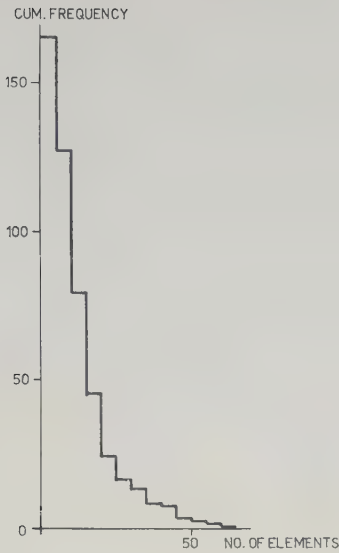


Fig. 6. A cumulative distribution of the 164 work-sequences (event-bse) observed for the 9 operators. Each interval on the x-axis represents an increase of 5 elements in the length of a sequence.

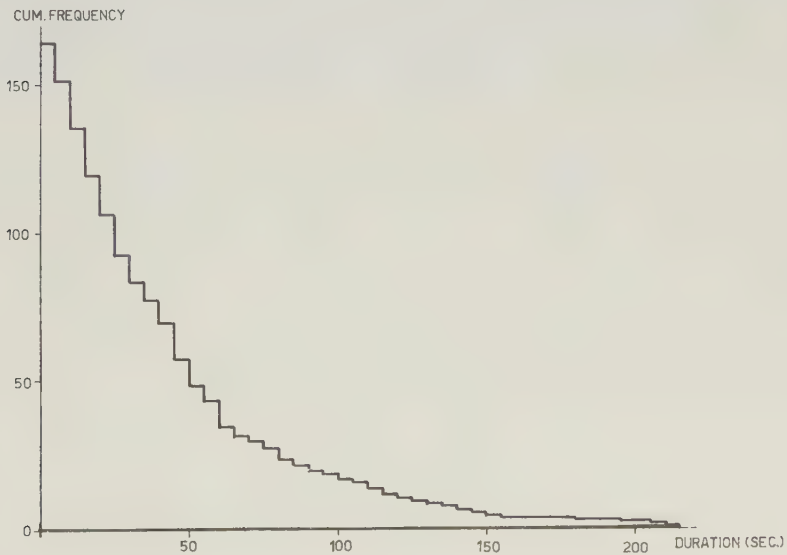


Fig. 7. A cumulative distribution of the 164 work-sequences (time-base) observed for the 9 operators. Each interval on the x-axis represents an increase of 5 seconds in the length of a sequence.

Discussion

In the analyses presented above, the main emphasis was placed, on the one hand, on identifying stable patterns in the behaviour of the telecom operators observed, and on the other hand, on discerning idiosyncratic differences in the work place behaviour of the individual operators. Both those endeavours are considered to have been successful. Thus, it was evident that there were two distinct groups of behavioural activities engaged in by the operators, the 'work-sequence' and the 'nonwork-sequence' where social and nonsocial activities not directly related to the work-sequence were performed. The work-sequence is fairly stereotyped and similar for all the operators. It tends to begin with the operator receiving an enquiry, progresses through a variable number of questions and answers from customer and operator, and ends with the operator throwing a switch to break the connection. The nonwork-sequence is, on the other hand, much more variable and tends to contain a different set of behaviour elements for the different operators. We have previously examined the event-state diagram of operator 05 which shows that her nonwork-sequence contains only the elements AUTO and ADJT, and no social interaction. Other operators have a more varied repertoire of behaviour elements in their nonwork-sequences, but the probability of engaging in the different activities varies widely. At the same time, the work-sequence profiles of the operators, as well as the relative amount of time spent in work activities, are quite similar.

Some systematic variation in the behavioural profiles may also be noticed between the two sub-tasks, VDU and MAN, but considerable care must be exercised in the interpretation of these differences because of the smallness of the present sample. However, there appears to be a real difference in efficiency, as measured by the length of time taken to expedite enquiries, between the two tasks. Thus, the mean length of time for this activity in work with visual display units is, in the present data, less than half that taken in the conventional, manual catalog-based enquiry service. As the mean number of behaviour elements that goes into this activity is about equal for the two tasks, the explanation for the difference must be that the search for information takes longer in MAN than in VDU (cf. Briem & Nyström, 1984, Table 2).

The high degree of similarity between the behavioural groupings observed and the element groupings inherent in the a priori taxonomy would indicate

that the design of the experiment was exerting an influence on the results from the study. This is, indeed, true. One must bear in mind that the a priori taxonomy was constructed on the basis of preliminary observations of the operators' behaviour, as well as other available information about the work situation. The close resemblance of the observed to the a priori taxonomic groupings is, therefore, a testimony to the appropriateness of the latter. Looking at this in another way, 'a priori' categories are defined before the empirical results, and form the basis for the taxonomy used to obtain the empirical data. Therefore, the a priori taxonomy is, in a sense, a hypothesis against which the observed reality is tested.

The natural groups of behaviour elements that exist in the telecom workplace behaviour itself depend primarily on the high degree of structure to be found in the task in hand. Thus, an expedition of a customer enquiry must have a beginning and an end, and during it relevant information is exchanged by the customer and operator. This encounter nearly always involves a search for information by the operator. At the same time, there are few external constraints on the number of exchanges involved and the time taken by the exchanges and the associated searches. We would expect that a normal enquiry should require a fairly fixed number of exchanges and a length of time to be expedited. But when is an enquiry 'normal'? How many questions and answers does it take for a normal customer to receive a normal answer from a normal operator based on the information contained in a normal database or/and set of directories? It should be clear that a definite answer to this question can only be given if all the parameters in the formula defining the 'normal' state of things are fixed. However, what we can do is set up limits for what we accept as 'normal', and on the basis of that detect deviations from the expected telecom operator behaviour. The deviant behaviour elements and sequences may further be characterized as being 'idiosyncratic', e.g. as when an operator begins to chat to a fellow operator in the middle of dispatching an enquiry, or 'unusual' e.g. as when an operator works faster or slower, is more helpful, brusque, chatty, efficient, impolite, etc., than would be expected from previous experience of telecom operators. In an observational study of the present kind, these types of relationships should be fairly easy to discern.

The question arises whether this type of observational study is more appropriate as a study of work behaviour than, for instance, an anecdotal type

of study, where the work place behaviour is represented in ordinary language in terms of short meaningful episodes occurring within the total behavioural stream. In the latter type of description, the observer tends to rely disproportionately on his private interpretation of what happens, and the representational instrument at his disposal is ordinary language with all its connotations and imprecision. Another result for the anecdote-type observer of not having a well defined shorthand to register his observations, is that the timing dimension of the observational sequence is largely reduced to the ordinal. Consequently, the choice of analytic techniques is more restricted. A similar critique may be levelled at some of the other more traditional observation methods, such as the critical incidents technique and time and motion study, which are also aimed at gathering information about specific work behaviour elements. On the other hand, the type of observation methodology used in the present report grants the investigator a greater freedom in choosing his analyses, while at the same time providing the means of rigorously planning the study from the beginning.

C o n c l u s i o n

Behaviour observation of work-place behaviour of the type described in the present study is a technique that has only been used in a limited way in the past. This is partly because of a lack of appropriate data-collection and analytic techniques. However, during the last two decades, a considerable amount of theoretical and practical knowledge has been generated within this area of methodology, but it is only recently that investigators have started using the available methods in applied research.

The present study is one of the first observational studies of its kind in organizational psychology, and it is to be hoped that the results will incite other investigators to do similar studies. Even if the sample used here is too small to allow us to draw any highly general conclusions about the present area of investigation, it should be sufficient to illustrate clearly the potentialities of this methodology. It shows how one can discern individual characteristics in the telecom operators' work-place behavioural style, as well as general trends in the behaviour of the group. It also allows us to extract from the results information about operators' efficiency, as well as the effectiveness of the tasks done, as shown by the performance of the group, and it gives us an opportunity to discern new

possibilities as to how improvements in existing job-routines may be introduced. Another possible extension of the present techniques, one which was not done in the present study, is in the analyses of the social interaction of the operators. We expect to have an opportunity to remedy this omission soon.

Notes

Note 1. Because of space-limitations, only one set of profiles, viz. the ones with RECV as the criterion category, is shown here. The reader is asked to take the author at his word regarding the other 9 profiles, and to refer to the appropriate Table (3 or 4) for the significant relations between categories in the group profiles.

Note 2. These relations are referred to by Hazlett & Bossert (1965) as 'directive' and 'inhibitive', respectively. However, these terms tend to suggest a causal connection between the behavioural events, a notion I prefer not to entertain in the present context.

Note 3. The normal use of state diagrams is with data of time-base type, where the same state may follow itself (cf. Miller & Frick, 1949, p. 315, Figure 3: 'Second order approximation of a series of dependent events'). The diagram consists of a number of 'nodes' and lines connecting them. The nodes represent behavioural states, and the lines probability paths between them. Given that the system is in a particular state, the probability that it will find itself in any other state is defined by the different paths and the probabilities associated with them. The usual relation represented by the paths is 'immediately succeeds', but any temporal relation may actually be represented. In an event-state diagram, a probability path must not lead back to the node from which it originated. Bakeman & Brownlee (1980) use state diagrams of this type, and refer to them (p. 875) as showing "'stae-based' (as opposed to 'time-based') transitional probabilities".

Note 4. It should be mentioned here that the conditional probability values and the related significance levels are dependent on both the categorical resolution of the behavioural taxonomy (i.e. the number of different categories used) and the temporal resolution of the behavioural record. These two parameters of the observational design are related. Thus, in general, a high taxonomic resolution is coupled to high conditional probability values while a high temporal resolution leads to low values, and vice versa for low resolutions. A more extended discussion of these relationships will be presented elsewhere.

Note 5. The actual sequences would not always begin with RECV, as this element would sometimes go by unnoticed. In that case the first element in the sequence would be GIVE. Similarly, the work-sequence would in a few cases not end with SWID, owing to the possible disappearance of very short responses in the transformation of the temporal resolution of the sequence from 0.1 second to 1 second (cf. Briem, 1983).

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**TEMPORAL ORGANISATION IN THE BEHAVIOUR
OF NEWBORN INFANTS IN ACTIVE SLEEP.**

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1)

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INTRODUCTION

Contrary to popular belief, the human neonate is at birth a highly competent creature, capable of performing a large number of different movements, both great and small. Most of this behaviour occurs when the infant is awake, but a surprising amount of behaviour occurs spontaneously and without any apparent outer stimulation when the infant is asleep. The observable infant sleep behaviour occurs chiefly in Active Sleep (AS), and only a small amount occurs in Quiet Sleep (QS) (cf. e.g. Nyström et al., 1977). Whereas much of the behaviour that the neonate engages in when awake, such as crying and many of the reflexes, is clearly biologically functional, sleep behaviour has sometimes been considered to be largely non-functional and lacking in intrinsic organisation. Thus, Prechtl (1965) describes the movements occurring in AS in the following way: "They consist of completely unorganized, irregular jerks and twitches, sometimes occurring in bursts and randomly involving eyes, face, neck, and limbs. ... This may reflect a 'physiological disintegration' of nervous function during certain periods of sleep." (p.89). Similarly, Prechtl and Lenard (1967), in a study of the Rapid Eye Movements (REM) occurring in neonates' AS, came to the conclusion that "the REMs are a complex noise phenomenon", accompanied by "an increase in frequency and irregularity of respiration, an increase in the amount of small muscular twitches and a depression of monosynaptic reflexes" (p.491). However, Nyström (1977) presents evidence for a certain degree of structural regularity in neonates' sleep behaviour in relation to a hypothetical "activation" variable. He proposes that behavioural organisation is a functional constant in the ontogeny of behaviour, and that it finds its expression in all states and stages of development. Whether the behaviour that may be observed in neonatal sleep is best described as primarily random or lawful is still an open question, one which the results presented below will hopefully throw some light on. But disregarding for the moment the degree of internal regularity and functional significance of infant sleep behaviour, we shall now examine its concrete expressions as well as its ontogeny and relation to other sleep phenomena.

There is a tendency to associate active behaviour with being awake and inactivity largely with being asleep. Sleep is associated with nighttime and being awake with daytime. This division is the rule as regards the normal, adult person, and is referred to as the "circadian" or "24-hour sleep-wake cycle" (cf. Kleitman, 1963). But it does not apply to young infants and neonates. In fact, a feature which stands out as one studies the behaviour of young infants is the fairly frequent periodic changes between states of high and low levels of activity. However, the circadian sleep-wake cycle begins to develop in the infant soon after birth, and is fairly well established at ca 20 weeks post partum (cf. Kleitman & Engelmann, 1953).

For the sake of simplification of description, Precht1 (1965) proposed the use of five different, relatively stable and durable states for the classification of infant activity. These states, which may be identified with a quite good inter-observer agreement, are numbered from 1 to 5 to indicate roughly an increasing degree of vigilance. States 1 and 2 are sleep states, referred to here as quiet and active sleep, respectively, while the other three states are used to describe wakefulness. Changes between states in the human neonate take place with a fairly high degree of sequential regularity. Thus state 2 tends to follow state 1 and be followed by either state 1 or state 3 etc. Although changes from one state to another are not immediate, the transitional stages are, as a rule, too short to merit being called states (Precht1, 1974; Precht1 & O'Brien, 1982).

State transition in young infants is characterised by a temporal regularity manifested in frequent periods of sleep with periods of wakefulness in between. It has been suggested that the regularity of this pattern depends on the existence of a universal, human activity cycle of which the observed behavioural state is an expression (Kleitman, 1963). The length of this cycle, commonly known as the "Basic Rest-Activity Cycle" (BRAC), was found by Kleitman (1963), citing his own findings and those of several other investigators (q.v.), to lie in the range of 80 to 90 minutes for adults and 50 to 60 minutes duration for infants. This has since been confirmed by several investigators, among them Sterman & Hoppenbrouwers (1971). These investigators present in their report evidence from both foetal and infant activity studies which indicate that this cycle is present in the human foetus at least as early as 21 weeks of gestation. Sterman & Hoppenbrouwers come to a similar conclusion as Kleitman, viz. that the cycle persists with some modifications into adult life and is probably the basis for the human circadian sleep-wake cycle. They identified two main activity cycles, 40 and 96 minutes in mean length, respectively, in the data from the 21-40 week old fetuses studied. The longer of these two cycles corresponds to the adult AS-QS periodicity of 90 minutes mean length reported by Kleitman, and Sterman and Hoppenbrouwers suggest that it may be imposed on the foetus through the mother's biological rhythms. The shorter one corresponds to the cycle length for infants reported by Kleitman (1963), as well as cycles in the range of 40-60 minutes' length found by Stern et al. (1973), and cycles of 60 and 61 minutes' mean length reported by Nyström (1975) and Nyström et al. (1977), respectively. Anders and Hoffmann (1973) reported for their infants phase-related EEG, EOG, EMG, and body movement patterns during AS and QS with periodicities of between 50 and 60 minutes. However, the actual length of the BRAC would depend to some extent on which criteria for the identification of sleep states were employed (cf. Dittrichova, 1969), as is indirectly confirmed in the quite considerable individual variation in cycle length reported by many investigators (cf. e.g. Dittrichova et al., 1976).

The identification of sleep states in the neonate is not entirely an easy matter (cf. Ashton, 1973). Thus, the EEG is not an infallible index as human neonatal brain activity is

somewhat different from that found in the adult (cf. Petre-Quadens, 1974), and various physiological criteria may indicate differently transitions from one stage to another (Dittrichova, 1969). This point is stressed by Dement and Mitler (1974) who state that "the criteria and the actual descriptive phenomenology of sleep in newborn infants is much more complicated than in human adults" (p. 281). It has also been suggested that environmental factors and disturbances in the sleep states due to situational stress may be a confounding effect in some polygraphic laboratory studies of infant sleep (Ashton, 1971; Bernstein et al., 1973). Even diet appears to affect the balance between the sleep states (Yogman & Zeisel, 1983). However, several behavioural indices, such as REM and irregular respiration have been used by many investigators for the identification of sleep state. Prechtl (1974) discusses at some length the behavioural qualities of the 5 states of activation proposed by him. He points out the arbitrary nature of the state variable and stresses that a clear consensus must exist as regards the criteria for determining the different behavioural states. Furthermore, Prechtl proposes that state should be identified entirely according to behavioural criteria, and suggests four such parameters, viz. 'eyes open', 'respiration regular', 'gross movements', and 'vocalization', ordered in binary vectors for this purpose. He states that "If the functional properties of the nervous activity turn out to be different in the various states (which are based on behavioural categories), the states must not only be considered as a descriptive behaviour classification, but as distinct modes of brain activity." (p. 186). Prechtl then goes on to offer evidence which supports a definition of states as conditions which reflect particular modes of nervous function, but at the same time he stresses that 'state' is not synonymous with 'level of arousal'.

An important aspect of the normal neonate's behavioural development is the change in the proportions and absolute amounts of time spent in the various states. By the third week of life the neonate is asleep over 60% of its time, and by the 26th week this proportion has decreased to about 55%. At the same time, 46% of the infant's sleep in the third week occurs between 8 a.m. and 8 p.m., but only 26% of its sleep occurs within that time interval by week 26. The length of the BRAC during this time is 50-60 minutes. In children of nursery school age the cycle length is 60-70 minutes, and by the time the child has grown up, the length of the cycle has become ca 90 minutes (after Kleitman, 1963). During sleep the BRAC expresses itself in transitions between AS and QS, and in the neonate the proportion of these two states is roughly 2:1 (cf. Nyström, 1975). The proportions in the duration of the various states in the young infant are fairly stable within certain limits, and deviations from them are likely to indicate neural abnormalities in the infant (Monod et al., 1972; Prechtl et al., 1973; Thoman et al., 1981).

Another ultradian activity cycle in infants was also noted by Kleitman (1963). This cycle was found to have 3-4 hours' periodicity, and was taken by Kleitman to be a "gastric" cycle, imposed on the infants through their feeding schedules. How-

ever, Gaensbauer and Emde (1973) showed that there does exist at the birth of the infant an activity cycle with a mean period of 4 hours independently of feeding schedules, and there is evidence (Meier-Koll et al., 1978) that this cycle persists at least until the fourth month after term. The transitions between sleep and the waking states may be an expression of this cycle.

REMs are the only reliable behavioural correlate of AS in the adult human being, although both gross and fine movements do occur with some regularity (Gardner & Grossman, 1975). The neonate has a far greater abundance of behavioural activity, both in AS and QS. Nyström (1975) investigated the usefulness of several behavioural items as sleep state indices. He found that behavioural item rate and eye movements behind closed eyelids were reliable indicators of sleep state, while irregular respiration was somewhat less reliable. Wolff (1966) had, among other things, observed that the incidence of spontaneous startles was higher in QS than AS, even though the former state contained far less activity than the latter. Nyström et al. (1977) confirmed this observation, and reported, furthermore, that one other behavioural item, trembling sigh, was more frequent in QS than AS, and that 10 other fairly infrequent behavioural items occurred solely in AS. However, it is probable that no single index can be used absolutely reliably to identify neonatal sleep state, and the use of multiple indices is, therefore, recommended (Precht & O'Brien, 1982).

It is against this background of state variations and activity rhythms that neonatal behaviour must be studied. As already mentioned, the neonatal peak activity periods tend to occur continually at ca 50 minutes' intervals, irrespective of the infant's state of wakefulness. During these periods the infant performs a variety of different actions, and in sleep, at least, behaviour is pretty well confined to the peak of the cycle (Nyström, 1975). The BRAC, seems to be already fairly well established in the human foetus after the 36th week of gestation (Sterman and Hoppenbrouwers, 1971; Stern et al., 1973; Precht et al., 1979), as is also the basic state organisation of the foetus (Nijhuis et al., 1984). Similarly, the results from a recent series of studies by Precht and his associates, aimed at discovering the development of behaviour from the early weeks of gestation onwards, indicate that foetal motility and that of preterm infants is fairly well developed at this age, although, of course, the development of posture and motility continues up to and beyond term (cf. Precht & Nolte, 1984).

Dement and Mitler (1974) point out that only one of the well defined sleep stages, viz. QS, contains recognised sub-stages (EEG stages 1-4), while no general division has been agreed upon for the other sleep state, AS. However, there are considerable similarities between the EEG characteristics of stage 1 and those of AS (Johnson, 1973 - cf. below), and the transition of those sleep stages tends to be via stage 2 (cf. e.g. Gillberg, 1983). Dement and Mitler also relate that when one divides the sleep of cats into "microepochs" corresponding to

EEG recordings of 3 consecutive seconds, it may be seen that for uninterrupted periods of NREM sleep, "the vast majority ... were very short, on the order of 1-2 min.", indicating a far more dynamic sleep process than is usually assumed to occur (p. 290). These relatively rapid shifts in the kind of sleep that the sleeper finds himself in can, however, not be seen as shifts in state which by definition is a more prolonged affair, recognisable by the presence of one or more state indicators. But what this phenomenon underlines is that there exist behavioural changes, perhaps mirroring cerebral activation, within and even beyond the more extended behavioural states.

Activity cycles of a relatively short duration in the sleep behaviour of human neonates have also been observed by Wolff (1966), with regard to individual behavioural elements, by Prechtl (1974), with regard to gross bodily movement, and by Nyström (1977), with regard to qualitative behavioural organisation. Thus, Wolff demonstrated a "rhythmic sequence" for the intervals at which three different behavioural elements tended to appear: Spontaneous startle in QS, with a mode at 45 seconds and a mean of 80 seconds; rhythmic mouthing in QS, with means between 4 and 14 seconds for the infants studied; and penile erections, with two modes at 30 and 150 seconds and a mean of 76 seconds in AS, and a mode of 15 seconds and a mean of 48 seconds in QS (cf. pp. 27-30). Prechtl presented data which shows that "transitory gross activity" in both AS and QS is characterised by recurring periods of increased activation, and the modal value of the non-sequential frequency distribution of the length of these periods is at 3 minutes (p. 195). A similar 3-minute rhythm also appears to exist in the REM activity of some neonates (cf. Prechtl & Lenard, 1967, Figure 5, p. 484). However, these investigators found no evidence of regular REM burst patterns in the sleep of their infants, of the type found in the AS of adults. Nyström (1977) showed that behaviour in AS tends to occur in bursts, whose contents of behavioural items was different both with regard to the intra-burst position and the burst length. He proposed a "threshold model" to explain this phenomenon, according to which "activation ... reaches and exceeds a certain threshold during recurring episodes of sleep. Above this minimum value activation is high enough to result in a burst of overt behaviour. Whenever this happens a triggering mechanism makes a random choice within a set of available sleep behaviours..." (p. 5). Nyström did not assess the length of any behavioural cycles possibly involved here.

The present study of infants' facial behaviour is intended to throw further light on the behavioural organisation inherent in the neonatal AS. In accordance with the evidence presented above, it is proposed that the behaviour observed in this state tends to recur with cyclic regularity, and that the quantity of these behavioural changes is related to the variations in physiological activation. It is also assumed that this activation is general in nature, and the results may, therefore, be generalised to the rest of neonatal behavioural organisation.

METHOD

Subjects

Eight neonates, 4 female and 4 male, aged 3-7 days, were filmed at the Neonatal division of the Department of Gynecology and Obstetrics, Lund University Hospital. All were healthy, full-term, normal-delivery infants whose mothers had stayed on at the hospital for a few days' rest post partum. Further information about the infants and the films of their facial behaviour is shown in Table 1.

Table 1. Characteristics of the neonates included in the study, the sequences contributed, and the observers. The last column shows the number of times that each of the three facial regions was registered by the observers.

Neonate	Sex	Age (days)	Sequences contributed		Observers	No. of registrations
			No.	Length (seconds)		
1	M	7	1	1330	EB,VB,JW	(2,2,2)
1			2	470	EB,VB,JW	(2,2,2)
2	M	6	3	1329	EB,VB,JW	(2,2,2)
2			4	490	EB,VB,JW	(2,2,2)
3	F	6	5	368	EB,VB,JW	(2,2,2)
4	M	4	6	763	EB,VB,JW	(2,2,2)
5	F	4	7	1200	EB	(2)
6	F	3	8	440	EB	(2)
7	M	3	9	193	VB	(3)
7			10	1200	EB	(2)
7			11	170	VB	(3)
8	F	3	12	164	VB	(3)
8			13	170	VB	(3)
8			14	170	VB	(3)

Apparatus

Two portable video recorders were used in the data collection on different occasions, an Akai 1/2", B/W, cassette recorder, and a SONY U-matic recorder. Some material was also collected on cinefilm with a soundproofed 16 mm BOLEX camera. Data registration was done with a MICRONIC 445 (M445) data collection terminal in "event-recorder" mode (cf. Briem, 1983).

Data collection procedure

The neonates were filmed on several different occasions during the first period of AS after the afternoon or evening feed. The filmed sequences ranged in length from ca 30 minutes (AKAI) through ca 20 minutes (SONY) to ca 170 seconds (BOLEX). The filming was done in an observation room where the lighting and recording equipment was set up. After the mother had fed the baby, changed its nappy, and it had fallen asleep, it was rolled into the observation room in its cot. There it was placed in a position relative to the filming equipment which made it possible to obtain films of acceptable quality, while at the same time keeping light, heat, and sound disturbances at a minimum. Video-recording was started when both REMs and

behaviour in the whole facial region had been observed, and recording continued as long as the tape lasted or the baby was asleep. The 16 mm films were shot round the middle of the REM periods.

Behaviour registration

Fourteen film sequences of varying length were selected for further analysis (cf. Table 1). The following selection criteria were applied: a) The film gave a clear view of the infant's face from forehead to chin, in at least semi-profile, b) the film was sufficiently clear, well exposed, and free from disturbances for the facial behaviour to be easily discernable, and c) the infant was in REM sleep, did not wake up during the sequence, and was not unduly restless with many gross head and body movements. REM sleep was here defined as occurring if REMs had been observed during the preceding three minutes of the sequence.

Each of the films was viewed a number of times by one or more observers (Os) (cf. Table 1, last two columns). The infant's face was divided into three regions, "Forehead", "Eyes", and "Lower face", and the behaviour in each of these three facial regions (FRs) was registered separately on different viewings as an all-or-none code. The division of the infant's face into regions is illustrated in Figure 1. During

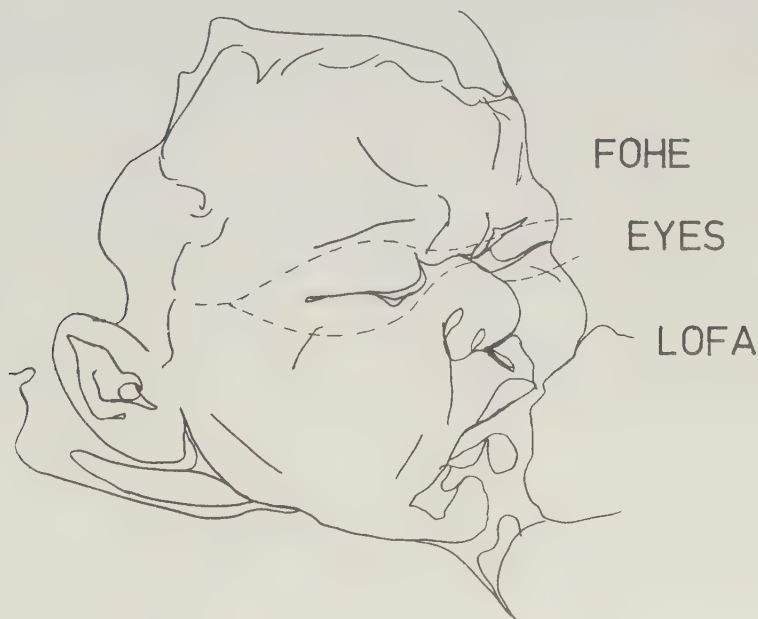


Figure 1. The facial behaviour of the infants was observed within each of the three facial regions, forehead (FOHE), eyes (EYES), and lower face (LOFA). EYES is outlined with a broken line, with FOHE above and LOFA below.

registration of a particular FR, the O would press down the appropriate key whenever any behaviour occurred within the FR, and keep the key pressed down as long as any behaviour was seen to occur in that FR. The resultant sequences would then consist of alternating behaviour and no-behaviour (NULL) codes. After transfer over a telecom link from the M445 to a Sperry-Univac 1100/80 mainframe computer, the recorded sequences were edited and transformed to Time-Base (TB) sequences (cf. Bakeman & Dabbs, 1976) with a resolution of 1 second in a series of application programs written by the present author. In these TB sequences, "1" designates the occurrence of behaviour, and "0" designates NULL.

The films numbered 1-8 and 10 (cf. Table 1) were viewed twice with respect to each of the FRs (i.e. 6 times altogether) by each of the Os of the particular films. These two registration sequences for an FR were combined to maximize the probability of obtaining a registration of behaviour that had actually occurred. As the temporal resolution was quite small, the two sequences for each O were adjusted for a common starting point after the best correspondence first having been obtained by the use of cross-correlation. For films 1-6, the registered sequences for each of the three FRs were then combined over the three Os, also after adjustment to a common starting point in the manner described above. Here, the combination of the three sequences for a given FR into a single sequence was accomplished through designating as "1" any 1-second period in the resultant sequence where the corresponding periods in at least two of the original sequences contained a "1", but as "0" those periods where only one or none of the original sequences contained a behaviour registration. Films 9 and 11-14 were viewed 9 times each, by one observer, three times for each of the three FRs. They were then combined in the in the same manner as the three sequences for each FR from films 1-6.

The multiple registration and subsequent combination of the sequences described above was designed to increase the probability of a) obtaining registrations of behaviour that actually occurred in the films observed, and b) excluding erroneous registrations. In other words, decreasing the likelihood of errors of omission and commission. The latter was also partly accomplished during the reduction of the temporal resolution of the TB sequences from 0.1 to 1 second, when behaviour recordings of less duration than 0.5 seconds were dropped from the record.

Observer agreement

The inter- and intra-observer agreement (Note 1) with regard to the registrations obtained at each successive second in the sequences was quite good, as may be seen from Table 2. Intra-observer agreement was assessed for all sequences with a cross-correlation, and some of these data are shown in Table 2a. The inter-observer agreement was assessed for the three pairs of Os for sequences 1-6 by obtaining the Kappa statistic of agreement for the registrations (cf. Table 2b; a computer program developed by Antonak, 1977, was used to calculate the Kappas). The

Table 2. Observer agreement: a) Intra-observer agreement, expressed as product-moment correlation coefficients, for the observers VB and JW, for filmed sequences 1-6. b) Inter-observer agreement, expressed as KAPPA/max.KAPPA, for the observers VB, JW, and EB, with regard to facial regions (FRs) 1-3, averaged over sequences 1-6.

a)		Film:	1	2	3	4	5	6
Observer		FR						
VB	1	.618	.659	.564	.465	.645	.655	
	2	.455	.221	.341	.462	.318	.265	
	3	.785	.694	.750	.696	.859	.649	
JW	1	.681	.628	.469	.528	.603	.422	
	2	.616	.216	.193	.481	.538	.220	
	3	.785	.620	.587	.671	.762	.642	

b)		FR	VB/JW	VB/EB	JW/EB	Mean
1		.667	.547	.482	.565	
	2	.453	.558	.262	.424	
	3	.868	.820	.707	.798	
Mean		.663	.642	.483	.596	

agreement measure actually shown here is the ratio of Kappa to max. Kappa (cf. Susman & Hollenbeck, 1984), and the size of this measure for the different pairs of Os and FRs was compared in an ANOVA (BMDP/P2V, Dixon & Brown, 1981). The results show that there is a significant difference in the agreement both between the three O pairs and the three FRs, $p < .001$ with respect to both factors, but no interaction between the factors.

Taxonomy construction.

At this point there were three registered sequences, one for each FR, for each of the films, and each of these sequences contained a good approximation of the actual behaviour occurring in the regions observed. These three sequences for each film were now combined in a single sequence representing the whole of the facial behaviour occurring in the film. The combinatory logic was simple: At any moment in time, there can occur behaviour in any one FR, any two FRs together, or all three FRs at the same time, or there is no observable behaviour of the kind to be recorded. All possible behaviour combinations may then be represented with an octal code. The taxonomy resulting from the combination of the single FR sequences is shown in Table 3. For convenience, the resultant behavioural units have been given acronymic labels, and it is by these labels that the units will be referred to henceforward. Furthermore, these units of facial behaviour may be organised hierarchically according to how great a part of the behaviour potentially occurring in the infant's face that they represent. Thus, the root of this tree, which is shown in Figure 2, represents behaviour occurring in all three FRs at the same time, level 1 represents behaviour in two FRs together, level 2 behaviour in single FRs, and level 3 NULL behaviour. Note that

Table 3. The taxonomy of neonatal REM sleep facial behaviour.

Facial region where behaviour occurs	Behaviour code	Acronymic label
No part of the face	0	NULL
Forehead	1	FOHE
Eyes	2	EYES
Forehead + Eyes	3	FOEY
Lower face	4	LOFA
Forehead + Lower face	5	FOLO
Eyes + Lower face	6	EYLO
All parts of the face	7	FELO

this tree is not properly a "hierarchy of classification" (cf. Dawkins, 1976), but rather a "hierarchy of connection" (cf. Nelson, 1973).

Thus, the final sequences used for subsequent analyses consisted of 8 different behaviour codes, representing activity in the three FRs and their combinations, or, alternatively, NULL behaviour. These sequences were truncated before analysis to a maximum of 10 trailing NULLs where a greater number than that existed at the end of a sequence.

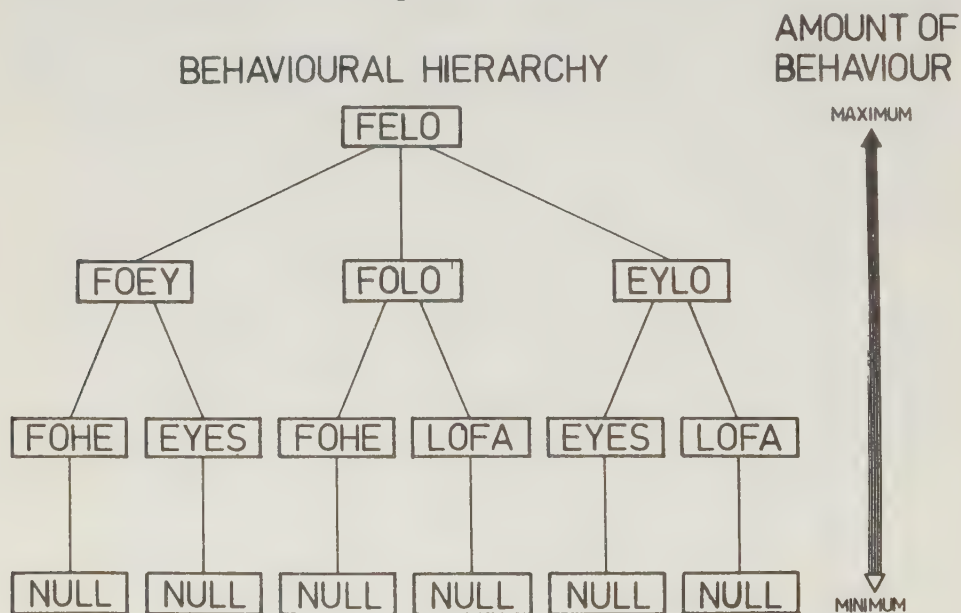


Figure 2. A behavioural hierarchy of connection, representing the neonatal facial behaviour. Transitions are expected to occur along the connecting lines in the hierarchy, and pendulate between maximum and minimum.

RESULTS

The first step in the analysis of the data was to obtain descriptive statistics of the behavioural elements in the 14 derived, composite sequences. The most relevant of these statistics are given in Table 4. It may be seen that the occurrences of the behaviour units tend to be of a fairly short duration, although there was a considerable variability within each unit. This indicates that the neonatal facial activity,

Table 4. Descriptive statistics for the 14 derived behaviour sequences. For each category within a sequence, the percent duration (%D) is given, together with the median (M) duration of the elements in the category and the associated $(Q3-Q1)/2$ (Q).

Category:		NULL	FOHE	EYES	FOEY	LOFA	FOLO	EYLO	FELO
Sequence no.									
1	%D	69.85	1.28	10.08	0.15	8.20	3.23	3.68	3.53
	M / Q	7 / 7	1 / 1	2 / 1.5	1 / 0	2 / 1	2 / 1	2 / 1.5	3 / 1
2	%D	50.64	0.21	23.62	1.06	10.64	1.91	5.53	6.38
	M / Q	3 / 3	1 / 0	2 / 1.5	1 / 0	1 / 0.5	1 / 0	1 / 0.5	2 / 0.5
3	%D	35.67	1.35	27.39	3.24	12.79	1.35	14.15	4.06
	M / Q	2 / 2.5	2 / 1	3 / 2	1 / 1	2 / 1.5	2 / 0.5	2 / 1	2 / 1
4	%D	67.96	0.00	14.69	1.02	9.18	1.02	4.08	2.04
	M / Q	5 / 3.5	0 / 0	2 / 1	1 / 1.5	2 / 1	2 / 0.5	1 / 0.5	1 / 0.5
5	%D	45.11	1.09	16.03	1.36	12.23	2.17	8.42	13.59
	M / Q	2 / 1	1 / 0	1 / 0.5	1 / 0	1 / 0.5	1 / 0	1 / 0.5	4 / 1.5
6	%D	67.10	1.05	15.86	2.10	7.99	0.79	4.19	0.92
	M / Q	4 / 3	1 / 0	1 / 1	1 / 0.5	1 / 1	1 / 0.5	1 / 0.5	1 / 0.5
7	%D	69.92	7.00	10.50	1.50	7.00	0.92	2.83	0.33
	M / Q	4 / 4	2 / 1	2 / 0.5	1 / 0.5	2 / 1	2 / 0.5	2 / 1	1 / 0
8	%D	71.82	7.05	5.68	0.00	9.55	2.50	2.27	1.14
	M / Q	4 / 3.5	2 / 0.5	2 / 0.5	0 / 0	2 / 0.5	1 / 0.5	1 / 0.5	1 / 0
9	%D	50.78	1.55	35.75	0.52	5.18	1.04	3.63	1.55
	M / Q	4 / 3	1 / 0	4 / 2.5	1 / 0	2 / 0.5	2 / 0	1 / 0.5	1 / 0.5
10	%D	61.67	2.58	11.92	2.58	13.17	1.42	5.25	1.42
	M / Q	4 / 3	1 / 0.5	2 / 1	2 / 0.5	3 / 1	1 / 0.5	2 / 0.5	1 / 0.5
11	%D	27.06	1.18	36.47	4.12	21.18	0.00	7.65	2.35
	M / Q	1 / 0.5	1 / 0	2 / 1	1 / 0	2 / 1.5	0 / 0	1 / 0.5	1 / 1
12	%D	16.46	0.61	18.90	4.27	23.17	1.22	21.34	14.02
	M / Q	2 / 0.5	1 / 0	1 / 1	1 / 0.5	2 / 2	2 / 0	2 / 0.5	1 / 1.5
13	%D	61.18	0.59	13.53	7.06	8.24	1.76	3.53	4.12
	M / Q	4 / 5.5	1 / 0	1 / 1	2 / 0.5	2 / 0.5	1 / 0.5	1 / 0	1 / 0
14	%D	48.24	2.35	20.59	5.29	16.47	0.59	4.71	1.76
	M / Q	3 / 1.5	1 / 1	2 / 0.5	1 / 1	1 / 2	1 / 0	1 / 0.5	1 / 0.5
Mean	%D	49.89	1.78	17.97	2.45	11.79	1.42	7.31	3.32
	S.D.	21.45	1.83	10.06	2.10	5.28	0.83	5.50	3.97

while present, was in a state of constant flux. But it was unclear if there was any method in this behaviour. The next step was, therefore, to test the hypothesis that the behaviour occurring in the three FRs could be that predicted from a simple random model (Note 2). According to this model, the resultant frequencies of the 8 derived behavioural elements would be those expected by chance, given the frequencies of NULL and the regional behaviour in each of the three original, adjusted sequences used in the derivation. The results from this test, which are summarised in Table 5, show conclusively that the behaviour occurring in the infants' faces during the AS periods is not random, but overlapping to a far greater extent than would be expected by chance, thus indicating that the behaviour is concentrated within well defined bursts.

Table 5. Random model testing of the data, comparing the proportion of sequences showing specific relations between the observed (O) and expected (E) behavioural unit percentages. One-tailed sign test probabilities are shown.

Relation	Proportion	p
pO(NULL)>pE(NULL)	13/14	<0.001
pO(FOHE)>pE(FOHE)	14/14	<0.001
pO(EYES)>pE(EYES)	11/14	<0.05
pO(LOFA)>pE(LOFA)	11/14	<0.05
pO(FELO)>pE(FELO)	14/14	<0.001
pO(FOEY)>pE(FOEY)	7/14	>0.05
pO(FOLO)>pE(FOLO)	8/14	>0.05
pO(EYLO)>pE(EYLO)	6/14	>0.05

One source of variation in the results that had to be examined at this point was the differences in the probability of occurrence of activity within the three FRs. As the particular FRs used in the study had been chosen primarily because of their anatomical distinction and ease of observation, no attempt had been made to include an equal number of muscular action units within each of them. Thus, it seemed that the difference in total duration of activity within the FRs might be due to a difference in the number of muscular units occurring. The units' duration was assumed to be equal. Using Hjortsjö's (1969) division into units of facial musculature, and calling these "Action Units" (AUs - cf. Ekman & Friesen, 1976), the Forehead region (F) is primarily affected by the action of 5 AUs and the Lower face region (L) by the action of 16 AUs. The Eye region (E) is primarily affected by only 3 AUs, but to this we must add 4 AUs which correspond to the ocular muscles. Actually, most of the facial and all the ocular muscles occur in pairs in the two sides of the face. But because of the conditions of the observation and the fact that more often than not both members of a pair act in unison, each muscle pair is considered as one AU only. If we now use this division into AUs as the basis for a prediction of action within the three FRs, treating the action in each as independent of the action in the other FRs, and taking into account the observed probabilities (pOs) shown in Table 4, then we can obtain expected probabilities (pEs) for the FRs by using the formula

$$pE(FR) = (1 - pO(NULL)) * \text{number of AUs in the FR} / \text{total number}$$

of AUs. The $pO(FR)$ is taken to be the sum of all the occurrences of activity in that FR, and they are: $pO(F) = .090$, $pO(E) = .311$, and $pO(L) = .225$, with a sum of .626. For the pEs we get: $pE(F) = .092$, $pE(E) = .129$, and $pE(L) = .295$, with a sum of .516. The pEs for F and L are quite similar to the pOs , while for E the pO is two and a half times the pE . Thus, the duration of activity in and around the the infants' eyes is far greater than what we would expect from the number of AUs involved. This lack of proportion was seen to be primarily due to movements of the eyes behind closed lids.

It was now evident that the neonatal facial behaviour during AS tended to occur in bursts of behaviour which often included more than one FR and were separated from each other by shorter or longer segments of NULL behaviour. However, in order to analyse the structure of the bursts of sleep behaviour, an acceptable definition of this concept was needed. It was decided that, in order to keep the definition as general as possible, while at the same time making maximal use of the material available, a "burst" would best be defined as "any occurrence of behavioural activity clearly separated from any other occurrence of behavioural activity by a segment of NULL behaviour". As it was considered that a single NULL might well occur spuriously in any behavioural sequence, a "segment of NULL behaviour" was taken to be any NULL behaviour lasting for at least two consecutive seconds (i.e. elements in the TB sequence). A count was made of the number of bursts in all the sequences, and their length and that of the NULL segments separating them was determined. The results are shown in Table 6. Here, the different sequences for infants 1, 2, 7, and 8 have been combined (cf. Table 1), and only figures for the combined sequences are shown for each of those infants. However, before combining the sequences, the means of the lengths of both the bursts and the NULL segments in the sequences to be combined were compared with a t-test, and found not to be significantly different. The bursts of behaviour and the NULL segments obtained for the 8 neonates were found to have median lengths of 4 and 5 seconds, with a $(Q3-Q1)/2$ of 4 and 3.5 seconds, respectively.

Table 6. The length of the NULL behaviour segments and bursts of behaviour.

Sequence	NULL behaviour			Behavioural bursts		
	N	MEDIAN	$(Q1-Q1)/2$	N	MEDIAN	$(Q3-Q1)/2$
1+2	89	7.5	6	88	4	3.5
3+4	91	5	3	90	6.5	3.5
5	31	3	2.5	31	3	3
6	58	5.5	3.5	58	3	2
7	68	5	5	68	3	2.5
8	24	6	7	24	4	3
9+10+11	101	5	3.5	100	5	3
12+13+14	33	4	3	32	6.5	5
	495	5	4	491	4	3.5

Ocular activity, in particular REMs, is often seen to occur before other facial activity, which may be taken to indicate that eye movements "drive" other facial behaviour. To test this assumption, bursts consisting of more than one different behavioural units, and beginning with a unit representing behaviour in a single FR, were counted for all the infants. The number of bursts beginning with EYES was compared with the number beginning with FOHE and LOFA, and the observed frequencies were 105 and 84, respectively. The corresponding expected frequencies were calculated from the probabilities of these units, as shown in Table 4, and equalled 107.66 and 82.38, respectively. The chi-square for these differences was 0.10 and non-significant.

Sequential cumulative distributions were then compiled for the behavioural units separately. Thus, for each unit, the behavioural elements occurring within all the bursts in all the sequences were plotted in at the second in time at which they occurred from the beginning of the bursts. The resultant distributions are shown in Figures 3a - 3h. For the distributions of NULL and the elements for the single-FR units, the mode is at 1 second from the start of the burst of behaviour. On the other hand, the mode of the multiple-FR unit distributions tends to lie at an interval of more than one second from the beginning of the bursts. Thus, the mode for the two-FR units is for FOEY at 2 seconds, for FOLO at 5 seconds, and for EYLO at 3 seconds from the start of the burst. The three-FR unit, FELO, has a distribution with several modes. A "best" estimate of the modal value was derived by first smoothing the distribution, and a curve whose single mode lay at 10 seconds from the start of the behavioural burst was then obtained. Thus, simultaneous behaviour in the two pairs of FRs where the regions are physically adjacent is seen to be most likely to occur at 2 and 3 seconds, respectively, in the non-adjacent pair at 5 seconds, and in all 3 FRs together at ca 10 seconds from the beginning of a burst of behaviour. The decay of the sequential distributions for the behavioural units from and including the mode was in all cases well described as geometric. The fitted geometric functions are inscribed on the distributions in Figure 3, and the equations included together with the squared correlation coefficients (i.e. explained variance).

A tentative structure in the AS behaviour had by now began to emerge from the analysis of the data. But a further effort was needed to discover the behavioural composition of the bursts. Two possible, alternative models for the behaviour suggested themselves, viz. a hierarchical activation model and a topographical model. According to the first model, changes from one behavioural element to another would occur in accordance with their position in the behavioural hierarchy described in the preceding section (cf. Figure 2), i.e. upwards or downwards along the paths connecting the different levels in the hierarchy, but not sideways or through jumps between levels. According to the second model, transitions between behavioural elements would be through a spread of activation across the boundaries between FRs. Thus, all transitions involving neighbouring regions would be likely to occur, while

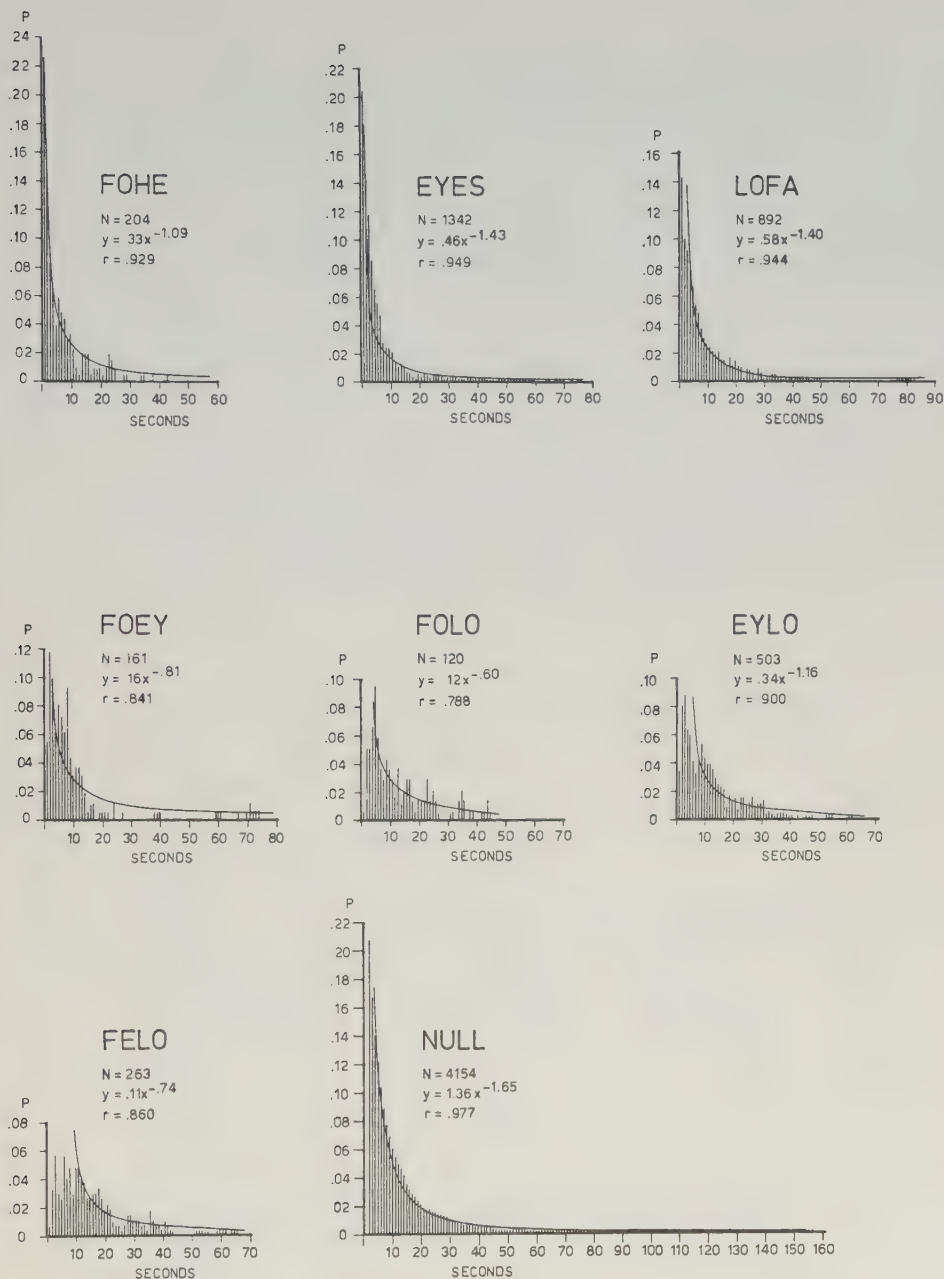


Figure 3. Sequential distributions showing the probability of occurrence for each of the infant active sleep facial behaviour units. Data from all 8 infants is combined, and the incidence of behaviour (7 units) is plotted for each second when the unit occurred from the beginning of a burst. Incidence of NULL is plotted from the cessation of burst of behaviour. Geometrical functions fitted to the data are shown together with the explained variance (r^2).

transitions from FOHE to LOFA and its combinations with other units, and vice versa, would be unlikely. These models were tested by first performing a lag sequential analysis (event-based) on the data (cf. Sackett, 1977), using a program written by Bakeman (1983) for the analysis. The results for the 8 infants were then subjected to a series of one-tailed sign tests, using as data the significant z-scores probabilities at lag 1 of all the behavioural units (cf. Bakeman, 1983). The results from these analyses are strongly in favour of the hierarchical model, as the predictions from this model are generally upheld, while the predictions from the topographical model are generally not. These results are summarised in Figure 4. The pooled conditional probabilities for the 8 infants and the associated z-scores are shown in Table 7.

The conditional probabilities in Table 7 are the ones for the whole group of infants, and here we can examine how far the probabilistic relations predicted from the hierarchical model agree with those obtained empirically. As may be seen in Figure 4, there are, according to the model, three specific transitions predicted for each of the facial behaviour units. These

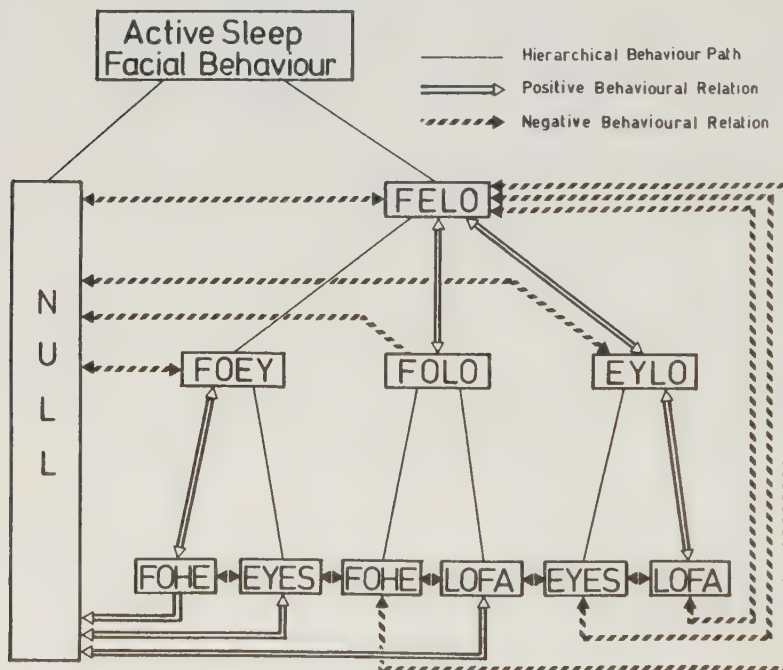


Figure 4. Statistically significant ($p < .05$) transitions between the units of the infants' facial behaviour. Positive relations (likely transitions) are traced with double lines, and negative relations (unlikely transitions) with broken lines. The direction of significant relations is marked with an arrow. Most of the significant relations are bidirectional.

Table 7. Percent conditional probabilities (p) and associated z-scores (z) for the 8 behavioural units at lag 1 (64 values). The p's and z's are for the pooled data for all 8 infants. The significance level chosen for the one-tailed sign test is 5% (indicated as "**"), but significance at the 1% level is also shown (indicated as "***"). The z-scores for unlikely p's are prefixed with a minus sign.

		FOHE	EYES	FOEY	LOFA	FOLO	EYLO	FELO	NULL
Criterion									
FOHE	p	----	9.9	8.6	4.0	5.1	1.4	2.1	69.0
	z	----	-3.06**	2.53**	-3.27**	1.24	-3.19**	-0.49	6.27**
EYES	p	1.7	----	8.1	5.6	0.1	13.8	2.2	68.6
	z	-4.09**	----	3.05**	-3.79**	-4.96**	-0.63	-4.42**	14.19**
FOEY	p	22.9	30.4	----	0.0	1.0	7.2	14.5	11.6
	z	8.01**	2.25*	----	-3.89**	-0.88	-1.38	3.85**	-3.30**
LOFA	p	1.3	6.6	0.0	----	7.3	28.3	2.3	54.3
	z	-4.35**	-9.10**	-4.14**	----	2.00*	8.90**	-2.98**	6.89**
FOLO	p	12.4	0.0	2.3	24.7	----	14.9	28.4	17.3
	z	3.36**	-4.63**	-0.58	2.11*	----	0.25	9.44**	-3.05**
EYLO	p	2.3	22.7	2.6	38.0	2.0	----	18.6	13.8
	z	-2.58**	-1.64*	-1.60	8.45**	-1.38	----	8.47**	-7.16**
FELO	p	0.9	1.3	10.0	22.4	29.3	32.8	----	3.3
	z	-1.77*	-5.35**	3.58**	0.20	14.44**	6.79**	----	-6.08**
NULL	p	12.0	54.8	2.1	27.3	0.4	3.1	0.4	----
	z	1.27	14.44**	-4.70**	2.53**	-6.45**	-10.44**	-7.84**	----
Simple									
p		2.8	22.4	1.5	17.3	5.9	11.6	7.2	31.2

transitions may be up and/or down in the hierarchy. The total observed conditional probabilities for each of the units along the expected paths may be summed as follows:

$$\begin{aligned}
 & p(\text{FOHE}/\text{FOEY}) + p(\text{FOHE}/\text{FOLO}) + p(\text{FOHE}/\text{NULL}) = .83, \\
 & p(\text{EYES}/\text{FOEY}) + p(\text{EYES}/\text{EYLO}) + p(\text{EYES}/\text{NULL}) = .91, \\
 & p(\text{LOFA}/\text{FOLO}) + p(\text{LOFA}/\text{EYLO}) + p(\text{LOFA}/\text{NULL}) = .90, \\
 & p(\text{FOEY}/\text{FELO}) + p(\text{FOEY}/\text{FOHE}) + p(\text{FOEY}/\text{EYES}) = .68, \\
 & p(\text{FOLO}/\text{FELO}) + p(\text{FOLO}/\text{FOHE}) + p(\text{FOLO}/\text{LOFA}) = .66, \\
 & p(\text{EYLO}/\text{FELO}) + p(\text{EYLO}/\text{EYES}) + p(\text{EYLO}/\text{LOFA}) = .79, \\
 & p(\text{FELO}/\text{FOEY}) + p(\text{FELO}/\text{FOLO}) + p(\text{FELO}/\text{EYLO}) = .72, \\
 & p(\text{NULL}/\text{FOHE}) + p(\text{NULL}/\text{EYES}) + p(\text{NULL}/\text{LOFA}) = .94.
 \end{aligned}$$

The observed conditional probabilities may be summed in a similar way for the negative relations predicted from the model. There is, of course, a certain amount of randomness in the process which makes it possible for most units to follow most others. However, practically all the predicted relations are highly significant statistically. The simple probabilities of the occurrence of the facial behaviour units are shown at the bottom of Table 7.

The sequential structure of the AS behaviour was further explored by the use of time-based lag sequential analyses of the sequences for 1-second lags up to lag 40 (cf. Sackett, 1977). The results from these analyses corroborated the previous findings from the event-based analysis, but did not

reveal any other, consistent, temporal patterns in the sequences.

Although the analyses had so far not shown conclusively the presence of temporal dependencies beyond the first one or two lags after a criterion between the behavioural units, it was considered distinctly possible that there might exist cyclic variations in the absolute amount of AS behavioural activity. To test this hypothesis, the 8 behaviour codes (0-7) were transformed to a discrete interval scale of 0-3, where, as before, "0" represented NULL, "1" represented behaviour occurring in one FR (FOHE, EYES, or LOFA), "2" behaviour occurring in two FRs (FOEY, FOLO, or EYLO), and "3" behaviour occurring in all three FRs (FELO). The data, thus transformed, were then used in a series of spectral analyses (BMDP/PlT, Dixon & Brown, 1981; see Note 3).

First, each of the 14 AS behaviour sequences was analysed separately. As the spectra for sequences from the same infants showed considerable similarities, they were concatenated, giving a single sequence for each infant, and the analyses repeated for these 8 longer sequences. Lastly, all 14 sequences were concatenated and a single spectral analysis made of the combined material. The results are shown in Table 8.

Table 8: The short-term facial behaviour activity cycles of the 8 infants.

Sequence:	1-2	3-4	5	6	7	8	9-11	12-14	MEAN	1-14
Cycle no.										
1	.	.	187	.	.	.	.	.	187	.
2	120	.	.	.	.	110	98	.	109	.
3	.	.	62	.	.	.	49	56	55	.
4	40	43	31	26	30	24	28	28	31	40
5	20	.	16	15	17	18	.	.	17	17
6	12	11	13	11	10	13	11	12	12	11
7	7.6	.	.	7.3	.	6.9	6.3	8.4	7.3	7.3
8	.	.	5.3	.	.	5.2	.	.	5.3	5.3
9	.	4.6	.	4.6	4.8	.	.	4.9	4.7	4.8
10	3.7	3.9	4.0	.	.	.	3.9	.	3.9	4.0
11	.	.	.	.	3.3	.	3.4	.	3.4	3.4
12	2.9	.	2.9	.	.	2.9	2.9	2.9	2.9	3.0
13	2.6	2.6	2.6	.	.	2.6	.	.	2.6	2.6
14	.	.	.	2.4	2.2	.	2.4	2.4	2.3	2.3
15	2.1	2.1	2.1	2.1	.	.	.	2.1	2.1	2.1

It appears that a characteristic series of cycles exists for each of the 8 sequences, but the spectral peaks are not exactly the same in the different cases. However, when the series are brought together, a system emerges where cycles of similar lengths may be seen to exist in the various series, although not all the cycles appear for all the infants. An average series of cycles was derived, and this series showed a considerable similarity to that for the 14 sequences combined (cf. Table 8). The average series cycle lengths were then plotted against their ordinal place in the series, and this plot is shown in Figure 5. A geometric function, fitted to the data points, turned out to describe the relationship very well (cf. inscribed function and explained variance in Figure 5).

CYCLE LENGTH IN SECONDS

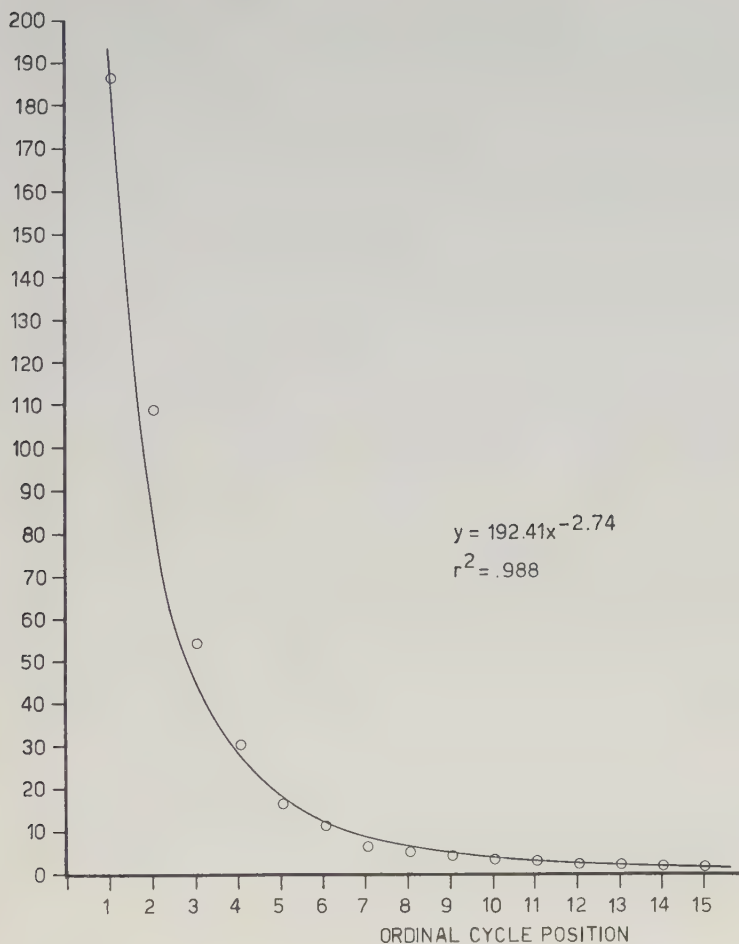


Figure 5. Average activity cycle lengths plotted against their ordinal positions. The fitted geometrical function is inscribed.

It was of considerable interest to see what longer cycles would be estimated through an extrapolation from the empirically determined data points. The values on the x-axis were, therefore, displaced two steps before fitting the function again. The two additional cycles then derived were 585 and 3914 seconds' (i.e. 9.55 and 65.23 minutes') long, respectively. The longer of the two extrapolated cycles is quite close to the upper limit for the infant BRAC established by previous investigators. In order to follow up this lead further, a new and longer series of cycles was postulated. This series contained three longer cycles in addition to the shorter empirically derived ones: 1) A 10-minute cycle, corresponding to the

shorter cycle derived in the extrapolation above, 2) the neonatal BRAC, assumed to be 50 minutes long, and 3) the 4-hour "gastric" cycle (cf. above). A geometric function, fitted to this series and shown in Figure 6, was found to leave less than 1% of the variation in the data unaccounted for!

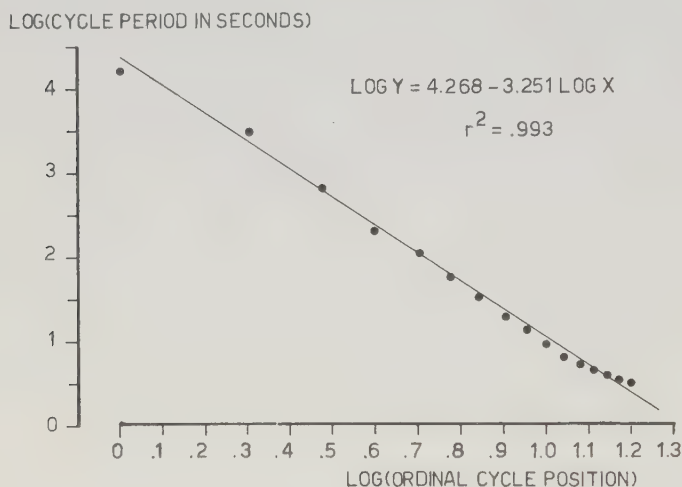


Figure 6. The average activity cycle lengths with three added cycles plotted against their ordinal positions in a log-log plot. The two longer of the added cycles, 240 and 50 minutes, correspond to known infant activity cycles, and the third, 10 minutes, is extrapolated from the function shown in Figure 5. A straight line provides a good fit.

DISCUSSION

Behaviour models

The AS behavioural organisation as shown in the results from the present study may be expressed in terms of a hierarchical threshold model similar to that proposed by Dawkins (1969). The model was originally designed to explain the choice behaviour of domestic chicks between a number of discreet responses. In it, the probability of a given response at any moment is considered to depend on the magnitude of an activation variable, V , so that a particular response only becomes available when V reaches a given level or threshold, when the responses seen at the lower levels of V are also available. The probability of any choice response was shown to be dependent on both its own characteristic probability and that of other responses available at the same time. In the final version of the model (Dawkins, 1976), the sequencing of behaviour is determined by transitions within

sets of behavioural units at the same hierarchical level and between sets at different hierarchical levels.

In the present study, changes in the total amount of behaviour, recorded in the three facial regions, F, E, and L, are taken to correspond to the variation in V, which in turn is regarded as an expression of the amount of "activation" available at a given moment. The observed behaviour is used to construct the hierarchical model of behavioural change. The units available at the higher levels in the model are combinations of the single units at the lowest level, and in this respect the model is similar to that proposed by Bastock and Manning (1955). The probability of the units at the different levels is not that expected simply from the probabilities of their components. In fact, the expected probability of the higher level units is relatively higher than that of the lower level units, indicating that when behaviour occurs, it tends to occur in bursts which involve more than one area of the face. The model is conditionally probabilistic, as the behaviour occurring at any moment is primarily determined by the behavioural occurrence at the immediately preceding moment, and the transitional probabilities used are those associated with the combination and breakdown of the basic behavioural units. Thus, changes in V are expressed in the changes in hierarchical levels in the model. Full-blown bursts of facial behaviour seldom appear suddenly, and the probability of behaviour increases gradually to a crescendo and then decreases, often through a succession of bursts.

But the changes in V in the bursts of observable behaviour, are only the crests of this wavelike activation. The regular recurrence of activity with periods of quiescence in between is the expression of a rhythmic process, and the most remarkable feature of the observed behavioural production is, in fact, its rhythmicity. The characteristic action is fairly well described as a complex of overlapping sine waves, where the component cycle periods of the compound wave are related to each other through a geometric function. This rhythm is regarded as being the behavioural expression of the activation variable, V.

Nyström (1977) also applied a threshold activation model to the AS behaviour of neonates. He proposed that sets of behavioural units become available at different times, and that these occurrences would show a predictable structure. Stipulating that bursts of behaviour had to be separated by at least 7 seconds of pause where no activity occurred, he isolated three separate clusters of behavioural items in his data. These sets of items could be discerned most frequently in pauses, at the beginning and ends of bursts, and in the middle of bursts, respectively. Short bursts tended to contain primarily items found at the beginning and end of longer bursts. Nyström did not specify the length of the intervals between bursts or attempt to trace any definite cyclic recurrences. However, as regards the sets of units occurring at different points in the bursts, it will be assumed that these are distinguishable with reference to their behavioural

complexity, as well as the identity of the AUs involved. Then, Nyström's results are, on the whole, consistent with the present results.

The more specific features of the behavioural sequences studied here may give rise to different interpretations of the behavioural production. Thus, it is possible to interpret the difference in intra-burst position of the multiple-FR taxonomic units as being due to a spread of activation across physiologically adjacent boundaries, either directly, through progressive sensory feedback from the face itself, or indirectly, through a spread of activation in parts of the nervous system isomorphic with the facial musculature. However, the evidence obtained in the present study is not consistent with a topographical model of this kind. Some decrease in transition latency between adjacent units could also be expected to occur owing to a difficulty during observation always to distinguish reliably between activity located on the boundary between regions. But this cannot be interpreted as spread of activation, and interesting as it may be to speculate around it, there is no reasonable indication of a topographical model of this kind being capable of explaining the behavioural phenomena observed here.

One interesting question that arises concerns the possible function of the AS facial behaviour observed here. Thus, we may speculate about the possibility of whether this behaviour is the expression of some "cognitive Plan", in the sense proposed by Miller et al. (1960). The fact that the behaviour is organised as previously indicated, supports the notion that it is directed from some sort of a CNS "program". Morrison (1983) has described the AS behaviour of cats with relatively small lesions in the pontine area of the brain. These preparations perform an extraordinary variety of seemingly meaningful actions, such as fighting and hunting, although the publicly observable object of this behaviour is, of course, always missing. These actions may, on one level, be seen as the outward expression of dreams, but on another, as the following through of behavioural Plans. Similar, but more fragmented actions have been elicited by animal preparations while awake by direct, electrical, cerebral stimulation (e.g. von Holst & von Saint-Paul, 1963; Willows, 1967). Behavioural elements elicited in this way have been suggested by Dawkins (1976) to be parts of behavioural hierarchies such as those described by Tinbergen (1950) and Baerends (1976).

The trouble with comparing the neonatal AS behaviour to the expression of a meaningful Plan is that the infants eliciting it have had scant opportunity to have their behaviour shaped in such a way as would ordinarily be considered as "meaningful", intelligent", or "cognitive". Furthermore, the behaviour occurs in the absence of external stimulation, or at least with external stimulation severely restricted. Consequently, the Plan that determines the AS behaviour must primarily be of an internal origin, and its unfolding ontogenetically determined.

The expression of activation in AS behaviour

The 3-minute behavioural activity cycle identified by Prechtl may also be observed in the present data, although here it is not very prominent. This may be the result of the limited length of the sequences studied here, or the difference in the behavioural units recorded. There is also a considerable variability within and between infants, as has been noted by previous investigators. Furthermore, the action of various factors may combine to obscure particular features of the AS behaviour. But sleep is by no means a unitary physiological phenomenon either. Dement and Mitler (1974) have, for instance, pointed out that the EEG stages observed in the sleep record are in a state of constant flux, with particular types of traces seldom lasting more than a few minutes at a time. As sleep may be viewed as both a behavioural and a physiological state, we can assume some correspondence between these two aspects, although maybe not a 1:1 relation. The compound behavioural cycle found in the present study is, therefore, assumed to have its counterpart in the infants' cerebral processes. On the whole, the evidence available at present is not indicative of the AS behaviour being the result of a disintegration of nervous function but rather a lawful, although perhaps not a highly meaningful process.

The nature of the relations between the observed AS behavioural phenomena and cerebral activity is still far from being clear. We know from the studies of Jouvet and others (cf. Morrison, 1983) that the organised sleep behaviour of cats with pontine lesions is accompanied by the EEG indicators of paradoxical sleep. Normal cats exhibit both REMs and other muscular twitches while in this EEG stage, as do normal human infants. We also know that these lesions within the RAS area of the midbrain function to remove the tonic inhibition that normally sets in during AS (cf. Morales & Chase, 1983). But what behavioural activity would we be able to observe in our neonates were this AS motor inhibition to cease? Would the behaviour observed be the same as that which we have observed, or would it be some more meaningful behaviour? Morrison (1983) has proposed that paradoxical sleep (PS) and alert wakefulness (AW) may be considered to be variations on the same neurological theme, mainly distinguishable by the motor inhibition present in the former state. A similar hypothesis was put forward by Johnson (1973). Considering the incomplete neurological development of the human neonate, it seems probable that the greater amount of overt AS behaviour, as compared to that seen in the adult, is due to a relative lack of motor inhibition in this neonatal state. A tentative conclusion might then be that the difference between the human neonate's behaviour when in the AW state and when in AS is analogous to the pontinely prepared cat's behaviour in AW and PS.

Cyclic changes in gross motor activity have also been shown in studies of adults' sleep behaviour. This activity sometimes occurs at the beginning and end of periods of AS,

but in between, only small muscular twitches and REMs may be observed, probably due to the centrally imposed tonic inhibition (cf. Gardner & Grossman, 1975). There may be a parallel here with the AS in infants, where, according to Prechtl (1974), REMs proper only begin ca 3 minutes after the onset of AS, and cease ca 3 minutes before the end of this period. On the other hand, slower eye movements are present throughout the AS period. Thus it seems that REMs are characteristic of that section of the AS period which in adults is characterised by tonic inhibition. Viewed in the context of the threshold model proposed earlier, these phenomena may be interpreted such that tonic inhibition sets in when activation rising to the crest of the BRAC reaches a certain threshold, and ceases when the ebbing activation drops below that threshold again.

The temporal resolution of the present data made it impossible to detect activity cycles of a shorter duration than 2 seconds. However, many of the phenomena which are seen in polygraphic recordings of sleeping people and which are of a finer temporal resolution than 1 second, such as REMs and the K-complexes of NREM sleep, occur spontaneously and with considerable regularity. Both of these particular phenomena are also closely connected with body movements and autonomic responses of various kinds, and it has been proposed by Johnson (1973) that they are related to changes in arousal. At a still finer level of resolution we have the EEG rhythms themselves, and even these rhythms appear to have their behavioural correlates. Byers (1976) has adduced evidence which indicates that many human motor phenomena, among them gestures and speech rhythms, tend to progress at rates which are multiples of 10 cycles per second, i.e. the normal cyclic period of the alpha rhythm which is so prominent in the awake EEG of human beings and other mammals. Similar temporal patterns have been observed in interaction studies of infants. Thus, in a series of experiments where newborn infants were presented with speech stimuli of adults speaking, either directly or from a tape recorder, Condon and Sander (1974) found that "the organization of the neonate's motor behavior is entrained by and synchronized with the organized speech behavior of adults in their environment". Lester et al. (1985) demonstrated the existence of a cyclic structure in the interaction of 3-5 months' old infants with their mothers. The periodicities of the interaction cycles found in their study were in the range of 10 to 45 seconds, and this range is similar to the middle of the range of cycles established in the present study. Lester et al. state (p. 25) that "It seems reasonable that biological rhythms could play a significant role in regulating early behavioural systems and are thought to reflect the presence of intrinsic neural oscillators or timing mechanisms in the nervous system".

The activation continuum and neural development.

Most higher organisms appear to be considerably influenced by the action of various biological rhythms, and it is apparent from the evidence adduced above that the human infant is no exception to this rule. It would seem that the foetus is, to begin with, under the influence of the mother's activity rhythms, and it is only after birth that the baby is fully autonomous in this respect. It is not clear yet when endogenous activity rhythms might first be observed in the foetus, but we know that some germinal neural activity is present from about the 6th week of gestation. By the 36th gestational week the rhythmic activation appears to have attained a relatively stable form, but the development and modifications continue until long after birth.

It was predicted at the beginning of the study that the AS behavioural production would vary rhythmically, although the form of this rhythmic activity was not specified in detail. Thus, it was not predicted that the series of activity cycles would be similar for all the infants. Neither was it predicted that the cycles in the derived series are related by a geometrical progression, nor that known activity cycles of longer duration than those possible to identify in the present data also appear to belong in this same progression. As this function model is post hoc it must, of course, be accepted with a measure of caution. But assuming its correctness, its significance is considerable. One possible way of testing the generality of these findings directly would be to look for the predicted 10-minute cycle, as this has not previously been observed in studies of neonatal behaviour. The discovery of such a cycle would provide a support for the model. A 12-minute activity cycle was identified in premature infants of 32 weeks' gestational age by Stern et al. (1973). But according to these authors, this activity cycle had been replaced by a 50 minute cycle (the BRAC) by the time the infants had reached 36 weeks' conceptional age. Another, more indirect way of testing the model would be by computer simulation. Such a test of the interaction between the 4-hour ultradian and the 24-hour circadian rhythms in the human neonate was performed by Meier-Koll et al. (1978), and shown to predict the sleep-wake rhythm very well.

The extrapolation to the longer activity cycles implies also extrapolation into other behavioural states than AS. Thus, the cyclic activation continuum cuts across the conventional state boundaries. The activity cycles proposed in the function model are obviously not the same as the so-called state indicators either, although there may be a relationship between them. But the identification of state is not always easy, and the validity of any particular indicator may be debated (cf. above). The differences in such factors as the classification of dependent measures, measurement techniques, and methods of analysis complicate the issue further. However, one thing that studies of activation and rhythms do have in common is that what is assessed is always activity of some sort, or a state corresponding to a general

level of activity during a given period. But considering the complications, it is remarkable that it is at all possible to predict from a simple function model such as the one found here the length of the activity cycles identified by the various investigators. The existence of a unifying phenomenon of this kind would serve to resolve many of the puzzles encountered in the study of the ontogeny and variability of organismic behaviour.

We have, by now, some idea as to the function of at least some of the variations in activity that the action of biological rhythms brings about. But we do, as yet, not know how or where the rhythms originate, what their collective function is, or why they actually exist at all. In the light of the knowledge that we have at the present time, it is possible to hazard some guesses, however. Thus, it seems plausible to suggest that in the development of the activity cycles, short cycles develop before long ones, and that as the longer cycles develop, the shorter cycles tend to become phase-locked into the longer ones. Also, it seems likely that cyclic activity, both in long and short behavioural cycles, is not random, but is governed by the same neurological principles as those which bring about the variation in what we normally refer to as "behavioural state", and that these principles regulate our activities and experiences throughout our lives. There is some evidence available which supports these proposals, but their confirmation or refutation will be the task of future research.

SUMMARY

The human neonate normally spends nearly $2/3$ of its time asleep, and of this time ca $2/3$ are spent in active sleep (AS). The present study was designed to investigate the temporal organisation and behavioural composition of this state. The hypothesis was put forward that the amount of facial behaviour that could be observed at any point in time during AS was representative of the neonate's general state of activation, and that the degree of activation varied with cyclic regularity. To test this, the facial behaviour of 8 normal neonates was filmed, and the films observed repeatedly. All activity occurring in three facial regions was registered and the resultant behavioural sequences analysed. It was found that facial behaviour tended to occur in bursts, and the median activity-quiescence cycle length was about 9 seconds. The amount of facial behaviour tended to wax and wane in a compound rhythm, and the lengths of the activity cycles involved could be predicted from a geometric function model. The results were compared with the evidence for cyclic behavioural activity found by previous investigators and several explanatory models were examined. It is proposed that the activity cycles observed here are related to the rhythmicity observed in other behavioural states of the human infant.

ZUSAMMENFASSUNG

Der Neugeborene verbringt fast 2/3 seines Tages im Schlaf und davon ist etwa 2/3 aktiver Schlaf (AS). Die vorliegende Arbeit wurde unternommen um den zeitmässigen Aufbau und die verhaltensmässige Zusammensetzung von AS zu untersuchen. Folgende Hypothese wurde geprüft: Die Menge von Gesichtsmerkmalen, die in jedem Zeitabschnitt des AS gefasst werden können, ist repräsentativ für den allgemeinen Aktivierungsgrad des Kindes. Weiter wurde angenommen dass der Aktivierungsgrad sich mit zyklischer Regelmässigkeit wiederholt. Um diese Hypothesen zu prüfen wurden 8 Neugeborene gefilmt und die Aufnahmen wurden mehrmals und von verschiedenen Personen observiert. Es wurde festgestellt dass die Gesichtsbewegungen in Gruppen aufzutreten tendierten und dass die Länge des median Aktivität-Ruhe-Zyklus etwa 9 Sekunden beträgt. Die Gesamtmenge von Gesichtsbewegungen neigten in einem zusammengesetzten Rhythmus zu- und abzunehmen, und die Länge der entsprechenden Aktivitätszyklen kann von einem geometrischen Funktionsmodell prediziert werden. Das vorliegende Resultat betreffend zyklischer Verhaltensaktivität wurde mit früheren Befunden verglichen und einige Erklärungsmodellen wurden geprüft. Es wird behauptet dass die gefundenen Aktivierungszyklen von dem Rhythmus in anderen Verhaltensstadien des Neugeborenen abhängig sind.

NOTES

Note 1: Observer agreement for behaviour is usually assessed with respect to event-based sequences of observed behaviour (cf. Bakeman & Dabbs, 1976). This implies that each point in the sequences compared corresponds to the occurrence or non-occurrence of a discrete event within a given time-interval where the behaviour was observed. In the present study, agreement is assessed from time-based sequences with a 1-second resolution. As this makes the registrations subject to such sources of variability as reaction time and vigilance of the observer, we can expect to obtain a somewhat lower agreement here than with event-based sequences.

Note 2: The expected behavioural unit probabilities (pE) in the composite behaviour sequences were calculated from the observed probabilities (pO) of behaviour in the three original FR sequences (F: Forehead, E: Eyes, L: Lower face):

$$\begin{aligned} pE(FOEY) &= pO(F) \times pO(E) \\ pE(FOLO) &= pO(F) \times pO(L) \\ pE(EYLO) &= pO(E) \times pO(L) \\ pE(FELO) &= pO(F) \times pO(E) \times pO(L) \end{aligned}$$

$$\begin{aligned}
 pE(FOHE) &= pO(F) - (pE(FOEY) + pE(FOLO) + pE(FELO)) \\
 pE(EYES) &= pO(E) - (pE(FOEY) + pE(EYLO) + pE(FELO)) \\
 pE(LOFA) &= pO(L) - (pE(FOLO) + pE(EYLO) + pE(FELO))
 \end{aligned}$$

$$\begin{aligned}
 pE(NULL) &= 1 - (pE(FOHE) + pE(EYES) + pE(LOFA) + pE(FOEY) \\
 &\quad + pE(FOLO) + pE(EYLO) + pE(FELO))
 \end{aligned}$$

Note 3: The use of spectral analysis for assessing the cyclicity in behavioural time series data measured on a categorical scale has been recommended by Gottman (1979). He demonstrated that the Fourier transform equation in the spectral model may be modified to accommodate categorical data. Spectral analyses of both the continuous and categorical versions of the same data were found by Gottman to be highly similar in all important respects. The main apparent difference was that the coherence spectrum for the dichotomous case was smoother than for the continuous one, presumably because of the loss of information in the binary scale transformation of the data.

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Appendix A.

A program package for the editing, transformation,
and analysis of sequential behaviour data.

Valdimar Briem

The collection, manipulation, and analysis of sequential data in behaviour observation studies can be a difficult enterprise without the help of automated data processing devices, specifically because of the large amounts of time series data to be processed. By now there are quite a few conceptual and computer technological devices available for this purpose, but usually the programs are specialized for application in particular projects, and are often difficult to get hold of. Therefore, it often happens that for the investigator who is familiar with computer programming the optimal way is to design and construct the necessary system himself in accordance with the requirements of the study in hand.

The program packet which I very briefly describe here was developed over a number of years specifically for the processing of the data gathered in my various behaviour observation projects. As I was already using a Micronic 445 data collection terminal at the time of the writing of the first of these programs, these were specifically concerned with the preliminary editing of the raw data in the particular format generated by that device, where the timing of the registered codes has a temporal resolution of 0.1 seconds. Another primary concern was to summarize the registered data and to derive appropriate descriptive statistics for them. The first version of these programs is described in some detail in Briem (1983).

At the present time the packet consists of about 30 greater and smaller programs for use in editing, storing, transforming, and analyzing the sequential data gathered in behaviour observation studies with the aid of a Micronic 445, or some other means of obtaining temporally based behavioural data. The programs may be run without modifications on any computer in the Sperry-Univac 1100 series, and the main programs, which are described below, may be run on most other mainframe computers with only minor modifications. Although the system is capable of being used as intended in its present form, it is not yet ready for final publication, as neither users' instruction manuals nor internal commentaries for use by other programmers are as yet available.

I have written most of the application programs in the computer language Simula. However, a number of additional statistical analysis programs, written in FORTRAN by other investigators, are also included (cf. below). These latter programs have been adjusted and extended to some limited extent before inclusion in the present package, partly to make it possible for them to be run on a Univac 1100/80 computer, and partly to fit the requirements of the program package as a whole. Furthermore, for each of the programs there exists one or more supporting programs of varying sizes, which I have written in CTS, and which are used for the input and output of instructions, for administering the transfer of data to and from computer files, as well as for the general administration of the system. These supporting programs are convenient and often necessary for the correct functioning of the program package. However, only the main programs included are described here.

The programs.

A. Data editing, description, and manipulation:

- A1. This program edits coded data which have been transferred from the data collection apparatus via a computer link to the host computer. The output may be inspected, and the editing completed interactively by the investigator.
- A2. This program tests the formal correctness of the data and outputs a summary which may be inspected before the data are analyzed.
- A3. The program calculates and outputs descriptive statistics for the sequences of coded data, such as measures of central tendency and variation, maxima and minima, rates of the production of the behaviour, histograms of behavioural durations etc.
- A4. This program transforms the data from a compact code with a temporal resolution of 0.1 second to digital sequences with a temporal resolution 1 second. During this process, registrations which are shorter than 0.5 seconds in duration are dropped, and the lengths of all registered units in the sequence are adjusted to conform to the 1-second resolution.
- A5. This program outputs extended ID codes and a summary of each of the registered sequences which have been input together in this same run; this output is then followed by the sequences themselves in their entirety, second for second.
- A6. This program performs auto- and cross-correlations of up to four input sequences at a time up to given number of lags ($\text{lag}(1)$), and writes out as tables the calculated correlation coefficients up to another given $\text{lag}(2)$, where $\text{lag}(1) \geq \text{lag}(2)$.
- A7. This program adjusts the input sequences to A6 before a renewed run of that program in order to maximize the cross-correlations obtained.
- A8. The program combines several recorded input sequences representing the same observed behaviour sequence in one either octal or cumulative output sequence in accordance with instructions (cf. Briem, 1986, Method).
- A9. The program transforms digital sequences of 1 second's temporal resolution to a sequential representation in compact code of 0.1 seconds' resolution for storage or repeated runs through A3 and other programs in the package.

B. Analysis.

- B1. This is a program for the calculation of Kappa and other related association statistics (Antonak, 1977).
- B2. ELAG: A program for 'lag sequential analysis' of behavioural data (Bakeman, 1983).
- B3. The program accepts output from ELAG, and transforms it into compact tables which are easy to overview; prepares the ELAG output data for further significance testing; and furthermore, prepares the data for graphic output.
- B4. This program outputs probability profiles (graphs) of the results from ELAG according to instructions contained in the output from B3 (cf. Briem, 1985).
- B5. This program may be used to obtain further tests of significance of the results from ELAG and B3; the results are output in summary tables (cf. Briem, 1985).
- B6. This is a self-contained program package for time series analysis (Williams & Gottman, 1982).

Listings of the programs as they stand at the moment, except for the program package by Williams and Gottman which is protected by copyright, may be obtained from the author on request. However, as I indicated previously, my own programs still lack written instructions for use and are not yet in such a form as is suitable for publication.

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